Introduction to Composting

A PermaCycle Tutorial

PermaCycle, LLC
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PermaScape

Introduction

Compost is one of nature's best mulches and soil amendments, and you can use it instead of commercial fertilizers. Best of all, compost is cheap. You can make it without spending a cent. Using compost improves soil structure, texture, and aeration and increases the soil's water-holding capacity. Compost loosens clay soils and helps sandy soils retain water. Adding compost improves soil fertility and stimulates healthy root development in plants. The organic matter provided in compost provides food for microorganisms, which keeps the soil in a healthy, balanced condition. Nitrogen, potassium, and phosphorus will be produced naturally by the feeding of microorganisms, so few if any soil amendments will need to be added.

Knowledge of composting is thousands of years old, and most gardeners have long understood the value of this rich, dark, earthy material in improving the soil and creating a healthful environment for plants. Understanding how to make and use compost is in the public interest, as the problem of waste disposal climbs toward a crisis level. Landfills are brimming, and new sites are not likely to be easily found. For this reason there is an interest in conserving existing landfill space and in developing alternative methods of dealing with waste. Why throw away nutritious organic soil enrichment materials when you can use them to improve your lawn and garden! Start composting instead.

Our hands our being forced to deal creatively with our own yard waste, as one by one, cities are refusing to haul off our leaves and grass clippings. About one third of the space in landfills is taken up with organic waste from our yards and kitchens, just the type of material that can be used in compost. With a small investment in time, you can contribute to the solution to a community problem, while at the same time enriching the soil and improving the health of the plants on your property.

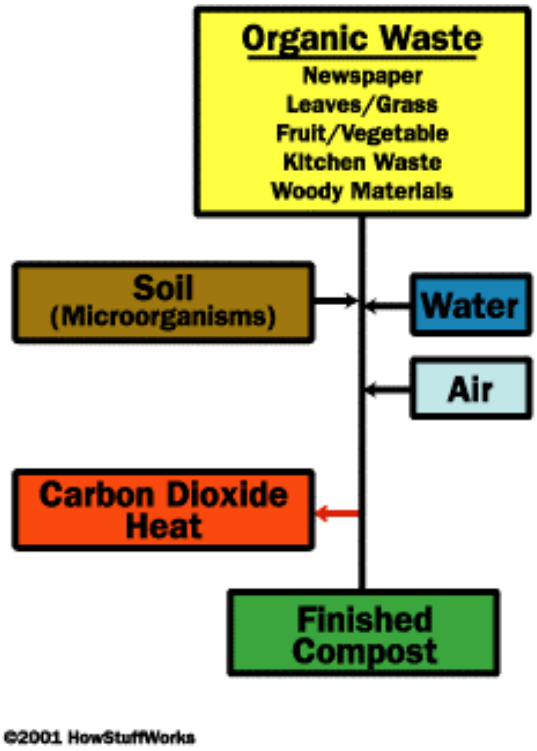
The Compost Decomposition Process

Compost is the end product of a complex feeding pattern involving hundreds of different organisms, including bacteria, fungi, worms, and insects. What remains after these organisms break down organic materials is the rich, earthy substance your garden will love. Composting replicates nature's natural system of breaking down materials on the forest floor. In every forest, grassland, jungle, and garden, plants die, fall to the ground, and decay as the small organisms living in the soil slowly dismantle them. Eventually these plant parts disappear into the brown crumbly forest floor. This humus keeps the soil light and fluffy.

All organic material will eventually decompose. The speed at which it decomposes depends on these factors:

- Carbon-to-nitrogen ratio of the material
- Amount of surface area exposed
- Aeration, or oxygen in the pile
- Moisture

- Temperatures reached in compost pile
- Outside temperatures



Carbon-to-Nitrogen Ratios
Carbon and nitrogen are the two fundamental elements in composting, and their ratio (C:N) is very significant. The bacteria and fungi in compost digest or "oxidize" carbon as an energy source and ingest nitrogen for protein synthesis. Carbon can be considered the "food" and nitrogen the digestive enzymes.

The bulk of the organic matter should be carbon with just enough nitrogen to aid the decomposition process. The ratio should be roughly 30 parts carbon to 1-part nitrogen (30:1) by weight. Adding 3-4 pounds of nitrogen material for every 100 pounds of carbon should be satisfactory for efficient and rapid composting. The composting process slows if there is not enough nitrogen, and too much nitrogen may cause the generation of ammonia gas that can create unpleasant odors. Leaves are a good source of carbon; fresh grass, manures and blood meal are sources of nitrogen.

The ratio of 30:1 is a guide incorporating a wide-range of feedstocks. The National Organic Standards Board (NOSB) reviewed the provisions in the USDA standard for processing and applying plant and animal materials and suggests that quality compost can be made with C:N ratios from as low as 15:1 and up to 60:1, adding that:

Site-specific variation in feedstock materials, management practices, and production requirements dictate that organic producers exercise flexibility in managing plant and animal materials on their operations.

In short, each producer must keep accurate records of the feedstocks, the amount, and condition that are being used; with the results of each production cycle recorded, including an independent lab analysis to provide a detailed accounting of the end product. By so doing, if a producer decides to market their product as organic, historical documentation will be available to support their application.

Surface Area
Decomposition by microorganisms in the compost pile takes place when the particle surfaces are in contact with air. Increasing the surface area of the material to be composted can be done by chopping, shredding, mowing, or breaking up the material. The increased surface area means that the microorganisms are able to digest more material, multiply more quickly, and generate more heat. It is not necessary to increase the surface area when composting, but doing so speeds up the process. Insects and earthworms also break down materials into smaller particles that bacteria and fungi can digest.

Aeration
The decomposition occurring in the compost pile takes up all the available oxygen. Aeration is the replacement of oxygen to the center of the compost pile where it is lacking. Efficient decomposition can only occur if sufficient oxygen is present. This is called aerobic decomposition. It can happen naturally by wind, or when air warmed by the compost process rises through the pile and causes fresh air to be drawn in from the surroundings. Composting systems or structures should incorporate adequate ventilation.

Turning the compost pile is an effective means of adding oxygen and brings newly added material into contact with microbes. It can be done with a pitchfork or a shovel, or a special tool called an "aerator," designed specifically for that purpose. If the compost pile is not aerated, it may produce an odor symptomatic of anaerobic decomposition.

Moisture
Microorganisms can only use organic molecules if they are dissolved in water, so the compost pile should have a moisture content of 40-60 percent. If the moisture content falls below 40 percent the microbial activity will slow down or become dormant. If the moisture content exceeds 60 percent, aeration is hindered, nutrients are leached out, decomposition slows, and the odor from anaerobic decomposition is emitted. The "squeeze test" is a good way to determine the moisture content of the composting materials. Squeezing a handful of material should have the moisture content of a well-wrung sponge. A pile that is too wet can be turned or can be corrected by adding dry materials.

Temperature
Microorganisms generate heat as they decompose organic material. A compost pile with temperatures between 90º and 140° F (32º-60º C) is composting efficiently. Temperatures higher than 140º F (60º C) inhibit the activity of many of the most important and active organisms in the pile. Given the high temperatures required for rapid composting, the process will inevitably slow during the winter months in cold climates. Compost piles often steam in cold weather. Some microorganisms like cool temperatures and will continue the decomposition process, though at a slower pace. In hot climates, it is essential that enough moisture be maintained in the pile to protect the microorganisms so that they can continue to do their job.

Summary
Humus is our goal when we start composting. By providing the right environment for the organisms in the compost pile, it is possible to produce excellent compost. We usually want to organize and hasten Mother Nature's process. By knowing the optimum conditions of heat, moisture, air, and materials, we can speed up the composting process. Besides producing more good soil faster, making the compost faster creates heat that will destroy plant diseases and weed seeds in the pile.

Compost Materials

Almost any organic material is suitable for a compost pile. The pile needs a proper ratio of carbon-rich materials, or "browns," and nitrogen-rich materials, or "greens." Among the brown materials are dried leaves, straw, and wood chips. Nitrogen materials are fresh or green, such as grass clippings and kitchen scraps.

Mixing certain types of materials or changing the proportions can make a difference in the rate of decomposition. Achieving the best mix is more an art gained through experience than an exact science. The ideal ratio approaches 25 parts browns to 1-part greens. Judge the amounts roughly equal by weight. Too much carbon will cause the pile to break down too slowly, while too much nitrogen can cause odor. The carbon provides energy for the microbes, and the nitrogen provides protein.

Leaves represent a large percentage of total yard waste. If you can grind them in a shredder/chipper or mow over them, they will reduce in size making them easier to store until you can use them in the pile, and they will decompose faster - an issue with larger leaves. They are loaded with minerals brought up from the tree roots and are a natural source of carbon. A few leaf species such as live oak, southern magnolia, and holly trees are too tough and leathery for easy composting. Avoid all parts of the black walnut tree as they contain a plant poison that survives composting. Eucalyptus leaves can be toxic to other plants. And avoid using poison oak, poison ivy, and sumac.

Pine Needles need to be chopped or shredded, as they decompose slowly. They are covered with a thick, waxy coating. In very large quantities, they can acidify your compost, which would be a good thing if you have alkaline soils.

Grass Clippings break down quickly and contain as much nitrogen as manure. Since fresh grass clippings will clump together, become anaerobic, and start to smell, mix them with plenty of brown material. If you have a lot of grass clippings to compost, spread them on the driveway or other surface to bake in the sun for at least a day. Once it begins to turn pale or straw-like, it can be used without danger of souring. Avoid grass clippings that contain pesticide or herbicide residue, unless a steady rain has washed the residue from the grass blades.

Kitchen Refuse includes melon rinds, carrot peelings, tea bags, apple cores, or banana peels - almost everything that cycles through your kitchen. The average household produces more than 200 pounds of kitchen waste every year. You can successfully compost all forms of kitchen waste. However, meat, meat products, dairy products, and high-fat foods like salad dressings and peanut butter, can present problems. Meat scraps and the rest will decompose eventually, but will smell bad and attract pests. Egg shells are a wonderful addition, but decompose slowly, so should be crushed. All additions to the compost pile will decompose more quickly if they are chopped up some before adding.

To collect your kitchen waste, you can keep a small container in the kitchen to bring to the pile every few days. Keep a lid on the container to discourage insects. When you add kitchen scraps to the compost pile, cover them with about 8" of brown material to reduce visits by flies or critters.

Wood Ashes from a wood burning stove or fireplace can be added to the compost pile. Ashes are alkaline, so add no more than two (2) gallon-sized buckets-full to a pile with 3'x3'x3' dimensions. They are especially high in potassium. Don't use coal ashes, as they usually contain large amounts of sulfur and iron that can injure your plants. Used charcoal briquettes don't decay much at all, so it's best not to use them.

Garden Refuse should make the trip to the pile. All of the spent plants, thinned seedlings, and deadheaded flowers can be included. Most weeds and weed seeds are killed when the pile reaches an internal temperature above 130 degrees, but some may survive. To avoid problems don't compost weeds with persistent root systems, and weeds that are going to seed.

Spoiled Hay or Straw makes an excellent carbon base for a compost pile, especially in a place where few leaves are available. Hay contains more nitrogen than straw. They may contain weed seeds, so the pile must have a high interior temperature. The straw's little tubes will also keep the pile breathing.

Manure is one of the finest materials you can add to any compost pile. It contains large amounts of both nitrogen and beneficial microbes. Manure for composting can come from bats, sheep, ducks, pigs, goats, cows, pigeons, and any other vegetarian animal. As a rule of thumb, you should avoid manure from carnivores, as it can contain dangerous pathogens. Most manures are considered "hot" when fresh, meaning it is so rich in nutrients that it can burn the tender roots of young plants or overheat a compost

pile, killing off earthworms and friendly bacteria. If left to age a little, however, these materials are fine to use.

Manure is easier to transport and safer to use if it is rotted, aged, or composted before it's used. Layer manure with carbon-rich brown materials such as straw or leaves to keep your pile in balance.

Seaweed is an excellent source of nutrient-rich composting material. Use the hose to wash off the salt before sending it to the compost pile.

The list of organic materials that can be added to the compost pile is long. There are industrial and commercial waste products you may have access to in abundance. The following is a partial list: corncobs, cotton waste, restaurant or farmer's market scraps, grapevine waste, sawdust, greensand, hair, hoof and horn meal, hops, peanut shells, paper and cardboard, rock dust, sawdust, feathers, cottonseed meal, blood meal, bone meal, citrus wastes, coffee, alfalfa, and ground seashells.

Table 1: Common Composting Materials

Type of Material	Use it?	Carbon/ Nitrogen	Details
Algae, seaweed and lake moss	Yes	N	Good nutrient source.
Ashes from coal or charcoal	No	N/A	May contain materials bad for plants.
Ashes from untreated, unpainted wood	Careful	Neutral	Fine amounts at most. Can make the pile too alkaline and suppress composting.
Beverages, kitchen rinse water	Yes	Neutral	Good to moisten the middle of the pile. Don't over-moisten the pile.
Bird droppings	Careful	N	May contain weed seeds or disease organisms.
Cardboard	Yes	C	Shred into small pieces if you use it. Wetting it makes it easier to tear. If you have a lot, consider recycling instead.

Cat droppings or cat litter	No	N/A	May contain disease organisms. Avoid.
Coffee ground and filters	Yes	N	Worms love coffee grounds and coffee filters.
Compost activator	Not required, but ok.	Neutral	You don't really need it, but it doesn't hurt.
Cornstalks, corn cobs	Yes	C	Best if shredded and mixed well with nitrogen rich materials.
Diseased plants	Careful	N	If your pile doesn't get hot enough, it might not kill the organisms, so be careful. Let it cure several months, and don't use resulting compost near the type of plant that was diseased.
Dog droppings	No	N/A	Avoid.
Dryer lint	Yes	C	Compost away! Moistening helps.
Eggshells	Yes	O	Break down slowly. Crushing shells helps.
Fish scraps	No	N/A	Can attract rodents and cause a stinky pile.
Hair	Yes	N	Scatter so it isn't in clumps.
Lime	No	N/A	Can kill composting action. Avoid.
Manure (horse, cow, pig, sheep, goat, chicken, rabbit)	Yes	N	Great source of nitrogen. Mix with carbon rich materials so it breaks down better.
Meat, fat, grease, oils, bones	No	N/A	Avoid.
Milk, cheese, yogurt	Careful	Neutral	Put it deep in the pile to avoid attracting animals.

Newspaper	Yes	C	Shred it so it breaks down easier. It is easy to add too much newspaper, so recycle instead if you have a lot.
Oak leaves	Yes	C	Shredding leaves helps them break down faster. They decompose slowly. Acidic.
Sawdust and wood shavings (untreated wood)	Yes	C	You'll need a lot of nitrogen materials to make up for the high carbon content. Don't use too much, and don't use treated woods.
Pine needles and cones	Yes	C	Don't overload the pile. Also acidic and decomposes slowly.
Weeds	Careful	N	Dry them out on the pavement, then add later.
Sod	Careful	N	Make sure the pile is hot enough, so grass doesn't continue growing.

Commercial Compost Site Selection

The location of the compost operation has many important implications. When choosing a site, consideration should be given to the direction of prevailing winds, and the impact associated with any odor, noise, dust, leaching and run-off. If in an outdoor location, composting should only be conducted on a compacted pad of low permeability, with at least 2 meters between the base of the piles and the underlying water table (see DPI Note Earth pad preparation requirements for deep litter pig production systems and solid waste stockpile and composting areas). If a mechanically turning container is used, some of the impacts of the outdoor operation are minimized or eliminated.

Drainage

Good surface drainage is essential for composting sites to avoid muddy conditions or excessively moist composting material. The slope of the composting site should be between 2% and 4% to ensure adequate drainage. Constructing the piles or windrows parallel to the slope will prevent the accumulation of water on the upside of the piles. Run-off from the site should be collected and contained in an existing effluent treatment system or through the use of appropriate bunding or a collection dam. Similarly, run-off from other sources should be directed away from the site.

Separation distances

Providing appropriate separation (buffer) distances between the composting operation and nearby water resources (surface and ground water) and neighboring houses can

help to minimise the impact of any odor associated with raw materials (such as manure) and protect the water resources from possible contamination. Separation distances will depend on local shire council recommendations. Piggery and feedlot operators should also consult DPI for separation distance requirements applicable to those industries.[1]

Seasonal Schedule for Composting

An effective storage system is the key to successfully using the materials each season provides. In the fall, collect and shred fallen leaves. The best use for them now is as mulch for trees, shrubs, and garden beds. Excess leaves can be stored - leaves from 100 bags can be shredded and put in a 4'x4'x4' container. Some decomposition will take place over the winter, but not a significant amount. Continue to put kitchen scraps in the pile, but it's not necessary to turn in cold climes. If you want your compost pile to stay active during the winter, you'll want an enclosed bin with insulated sides. A black bin situated in a sunny spot can help trap solar radiation during cold spells. Keep the pile as large as possible so that heat generated from decomposition will endure. You can also stack bales of straw along the sides of your bin to help retain the heat.

In areas with a cold winter, spring is the best time to start the compost pile in earnest. There's an abundance of grass clippings and trimmings. Summer is the time the compost pile is working at its peak range of decomposition, especially if it has been turned once or twice. Cover and store the finished compost, or use it, and start another batch. With enough organic waste, you can produce several batches of highly managed compost during the summer.

Making Compost

Composting methods can range from passive - allowing the materials to sit and rot on their own – to being highly managed. Whenever you intervene in the process, you're managing the compost. How you compost is determined by your goal. If you're eager to produce as much compost as possible to use regularly in your garden, you may opt for a more hands-on method of composting. If your goal is to dispose of yard waste, a passive method is your answer.

Passive composting involves the least amount of time and energy on your part. This is accomplished by collecting organic materials in a freestanding pile. It might take a long time (a year or two), but eventually organic materials in any type of a pile will break down into finished compost. More attractive than a big pile of materials sitting in your yard is a 3-sided enclosure made of fencing, wire, or concrete blocks, which keeps the pile neater and less unsightly. Add grass clippings, leaves, and kitchen scraps (always cover these with 8" of other material). The pile will shrink quickly as the materials compress and decompose. Wait a year or two before checking the bottom of the bin for finished compost. When it's ready, shovel the bottom section into a wheelbarrow and

[1] For more information on determining appropriate separation distances see the Reference manual for the establishment and operation of beef cattle feedlots in Queensland and the Separation guidelines for Queensland piggeries (visit: www.dpi.qld.gov.au/ilsu/4941.html or phone +61 7 4688 1305).

add it to your garden beds. Continue to add greens and browns to have a good supply of finished compost at the ready. After the first few years, most simple piles produce a few cubic feet of finished compost yearly.

Managed composting involves active participation, ranging from turning the pile occasionally to a major commitment of time and energy. If you use all the techniques of managing the pile, you can get finished compost in 3-4 weeks. Choose the techniques that reflect how much you want to intervene in the decomposition process and that will be a function of how fast you want to produce compost.

The speed with which you produce finished compost will be determined by how you collect materials, whether you chop them up, how you mix them together, and so on. Achieving a good balance of carbon and nitrogen is easier if you build the pile all at once. Layering is traditional, but mixing the materials works as well.

Shredded organic materials heat up rapidly, decompose quickly, and produce uniform compost. The decomposition rate increases with the size of the composting materials. If you want the pile to decay faster, chop up large fibrous materials. You can add new materials on an ongoing basis to an already established pile. Most single-bin gardeners build an initial pile and add more ingredients on top as they become available.

The temperature of the managed pile is important - it indicates the activity of the decomposition process. The easiest way to track the temperature inside the pile is by feeling it. If it is warm or hot, everything is fine. If it is the same temperature as the outside air, the microbial activity has slowed down and you need to add more nitrogen (green) materials such as grass clippings, kitchen waste, or manure.

If the pile becomes too dry, the decay process will slow down. Organic waste needs water to decompose. The rule of thumb is to keep the pile as moist as a wrung-out sponge.

If you're building your pile with very wet materials, mix them with dry materials as you build. If all the material is very dry, soak it with a hose as you build. Whenever you turn the pile, check it for moisture and add water as necessary.

Too much water is just as detrimental as the lack of water. In an overly wet pile, water replaces the air, creating an anaerobic environment, slowing decomposition.

Air circulation is an important element in a compost pile. Most of the organisms that decompose organic matter are aerobic - they need air to survive. There are several ways to keep your pile breathing. Try not to use materials that are easily compacted such as ashes or sawdust, without mixing them with a coarser material first. People who build large piles often add tree branches or even ventilation tubes vertically into different parts of the pile, to be shaken occasionally, to maximize air circulation.

A more labor-intensive way to re-oxygenate the pile is to turn the pile by hand, using a large garden fork. The simplest way is to move the material from the pile and restack it alongside. A multiple-bin system makes this efficient, in that you only handle the material once. Otherwise, you can put the material back into the same pile. The object is to end up with the material that was on the outside of the original pile, resting in the middle of the restacked pile. This procedure aerates the pile and will promote uniform decomposition.

The following information is for the highly managed pile and the optimum finished compost in the shortest amount of time. Decomposition occurs most efficiently when the temperature inside the pile is between 104 degrees F and 131 degrees F. Compost thermometers are available at garden shops and nurseries. It is best not to turn the pile while it is between these temperatures, but rather when the temperature is below 104 degrees F or above 131 degrees F. This keeps the pile operating at its peak. Most disease pathogens die when exposed to 131 degrees for 10-15 minutes, though some weed seeds are killed only when they're heated to between 140 degrees and 150 degrees. If weed seeds are a problem, let the pile reach 150 degrees during the first heating period, then drop back down to the original temperature range. Maintaining temperatures above 131 degrees can kill the decomposing microbes.

As the composting process nears completion and the microbial activity slows down, the temperature drops and the compost begins to mature. To produce mature compost, a curing of from one to 4 months is required.

The Compost Bin

Click on photos to get more information and pricing about each compost bin.
To save space, hasten decomposition, and keep the yard looking neat, contain the compost in some sort of structure. A wide variety of composting structures can be purchased, or made from a variety of materials. They can be as simple or complex as desired.

Yard wastes can be composted either in simple holding units, where they will sit undisturbed for slow decomposition, or in tumbling compost bins, which produce finished compost as quickly as just a few weeks with a good mix of materials.

Holding units are simple containers used to store garden waste in an organized way until these materials break down. A holding unit is the easiest way to compost. It only requires placing wastes into a pile or bin as they are generated. Non-woody materials such as grass clippings, crop wastes, garden weeds, and leaves work best in these systems. A holding unit can be a cylinder formed of wire (chicken wire is too weak to hold up to the bulk), or wood scraps. Openings in the sides need to be large enough to permit plenty of air, but small enough to contain the materials that are composting.

Turning units are typically a series of bins used for building and turning active compost piles. A turning unit allows wastes to be conveniently mixed for aeration on a regular basis.

Home gardeners are constantly inventing creative and inexpensive ways to hold their compost - for example, bins made from wire mesh or from shipping pallets.

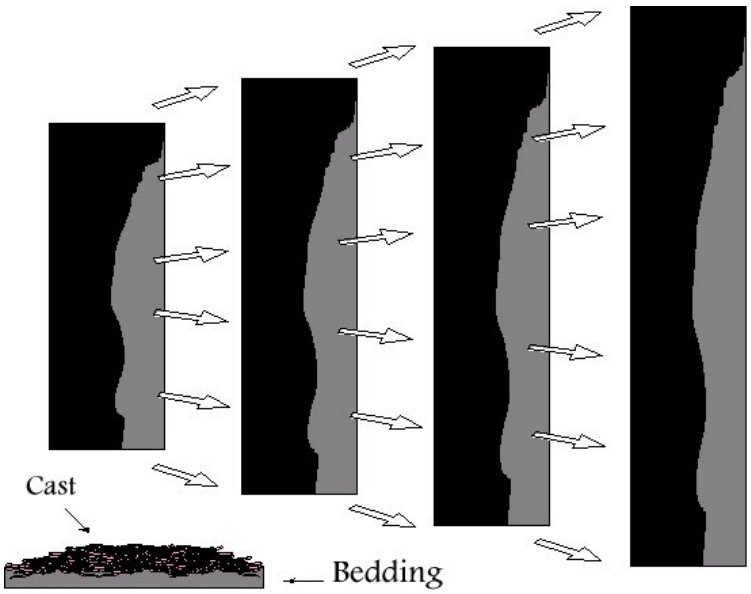
Some gardeners lash together four pallets, leaving one corner loosely attached to act as a door. Others install posts in four corners, nail the pallets to the posts to form three sides of the bin, and wire the last pallet with some slack to allow access. Make a simple, three-sided bin by stacking concrete or cinder blocks. Leave the fourth side open for turning the pile or for access to the finished compost.

Renewed interest in recycling has prompted a great increase in the types of composting systems available commercially. Consider the advantages and disadvantages of each type of compost bin to choose the best one for your yard, budget, and life-style. They range from wire containers to plastic bins and tumblers.

Windrow Composting

Compost can be produced in windrows with great efficiency. Organic waste is formed into rows of long piles (windrows) and aerated either by embedding pipes in the pile or by turning the pile periodically. This method can accommodate large volumes of waste, including animal products or grease, but only with frequent turning and careful monitoring during the thermophilic stage (when the pile reaches 130° to 150° Fahrenheit).

Windrows are typically triangular-shaped rows from 4-ft (1.5m) high, 6 to 8-feet (2-3m) wide at the base, about 3-ft (1m) wide at the top, and as long as necessary.



Turning for aeration is done about once a month using a front-end loader or other type of heavy equipment made specifically for that purpose, such as a mechanical windrow turner.

Check the temperature and moisture levels twice a week. The finished compost may be sold, given away, exchanged for labor, or used by the municipality in public works projects, such as soil remediation and landscaping.

With adequate rainfall and aeration, the composting process takes 90 to 120 days. After the compost meets temperature, turning, and processing time guidelines, it is transferred to a covered storage curing area for drying and screening.

In-vessel Composting

Organic materials are stored in enclosed equipment with controlled temperature, moisture, and aeration. This type of system can process large quantities of waste with fewer odor problems in a small area and can accommodate animal products.

Odor and Pest Control

A smell emanating from the compost pile may mean the microorganisms are not getting enough oxygen. To deal with odor problems, adjust the inputs, especially oxygen. See the Troubleshooting Guide in the section below to determine the cause of the problem. A layer of straw, sawdust, or mature compost can be placed on top of the piles to contain odors and to keep out pests.

Economics of Composting

To determine whether or not composting is an economically viable enterprise in a given area, it will be necessary to perform a rough economic assessment of the planned operation. Compost wholesales at between $16 and $35/yd^3.[2] An economic analysis could include:

- Selling price
- Local market requirements
- Site requirements
- Compost amendment costs in local market
- Machinery and labor costs (including screening)
- And, most importantly, identifying costs associated with currently managing organic waste material, instead of composting it (e.g. landfill disposal costs, manure stockpile operation, etc.).

[2] This is a rough guide only. Please make appropriate inquiries as part of your economic assessment.

PermaCycle's Compost Operation Action Plan™

Table 4 projects 12 essential steps consistent with PermaCycle's technical approach to implementing an industrial composting system. Several of these steps are currently practiced at composting facilities worldwide. Source separation and materials auditing are central to instituting any recycling enterprise.

Table 2: Compost Operation Action Plan

Step	Action
1	Establish a Source Separate Collection System.
2	Audit organic materials hauled on site.
3	Identify material(s) that can be processed by composting.
4	Complete site permitting procedures and await authorization.
5	Determine volume requirements and formula blends.
6	Evaluate site selection and identify environmental/health considerations.
7	Establish monitoring and management procedures.
8	Establish product standards.
9	Harvest, cure, and store compost.
10	Educate stakeholders about uses, benefits, and risks associated with compost.
11	Institute Quality Assurance Program.
12	Activate Project Monitoring & Review Process

Troubleshooting

Making compost is really quite easy, but having too much of a certain material or letting the compost get too wet or too dry can cause problems.

Table 3: Common Composting Problems

Problems	Possible Causes	Solution
Damp and warm only in the middle of the pile.	Pile could be too small, or cold weather might have slowed composting	If you are only composting in piles, make sure your pile is at least 3 feet high and 3 feet wide. With a bin, the pile doesn't need to be so large.
Nothing is happening. Pile doesn't seem to be heating up at all.	1. Not enough nitrogen 2. Not enough oxygen 3. Not enough moisture 4. Cold weather?	1. Make sure you have enough nitrogen rich sources like manure, grass clippings or food scraps. 2. Mix up the pile so it can breathe. 3. Mix up the pile and water it with the hose so that there is some

		moisture in the pile. A completely dry pile doesn't compost. 4. Wait for spring, cover the pile, or use a bin.
Matted leaves or grass clippings are not decomposing.	Poor aeration, or lack of moisture.	Avoid thick layers of just one material. Too much of something like leaves, paper or grass clippings don't break down well. Break up the layers and mix up the pile so that there is a good mix of materials. Shred any big material that is not breaking down well.
Stinks like rancid butter, vinegar or rotten eggs.	Not enough oxygen, or the pile is too wet, or compacted.	Mix up the pile so that it gets some aeration and can breathe. Add course dry materials like straw, hay or leaves to soak up excess moisture. If smell is too bad, add dry materials on top and wait until it dries out a bit before you mix the pile.
Odor like ammonia.	Not enough carbon.	Add brown materials like leaves, straw, hay, shredded newspaper, etc.
Attracts rodents, flies, or other animals.	Inappropriate materials (like meat, oil, bones), or the food-like material is too close to the surface of the pile.	Bury kitchen scraps near the center of the pile. Don't add inappropriate materials to compost. Switch to a rodent-proof closed bin.
Attracts insects, millipedes, slugs, etc.	This is normal activity in composting, and part of the natural process.	Not a problem.
Fire ant problems.	Pile could be too dry, not hot enough, or has kitchen scraps too close to the surface.	Make sure your pile has a good mix of materials to heat up, and keep it moist enough.

Vermicomposting

Vermicomposting, or worm composting, is different than traditional composting.

Worm composting is a process that uses red earthworms (also commonly called “redworms”), to consume organic waste, producing castings (an odor-free compost product for use as mulch), soil conditioner, and topsoil additive. Naturally occurring organisms, such as bacteria and millipedes, also assist in the aerobic degradation of the organic material.

Vermicomposting or worm composting is the easiest way to recycle food wastes and is ideal for people who do not have an outdoor compost pile. Composting with worms avoids the needless disposal of vegetative food wastes and enjoys the benefits of high quality compost. It is done with "redworms" (Eisenia foetida) who are happiest at temperatures between 50º and 70º F and can be kept indoors at home, school, or the office. As with outdoor composting, it is best to avoid putting bones, meats, fish, or oily fats in the worm box as they emit odors and may attract mice and rats. When cared for properly, worms process food quickly and transform food wastes into nutrient-rich "castings." Worm castings are an excellent fertilizer additive for gardens or potted plants.

The redworms are placed in a box or bin that can be built or purchased, along with “bedding” of shredded cardboard and/or paper moistened to about 75% water content. The container should be wide enough so that food scraps can be buried in a different location each time. The dimensions of the container and the amount of worms required initially will depend on how much organic food waste will need to be composted each week.

The worms will gradually reproduce or die according to the amount of food they receive. A sudden addition of a large amount of food waste may attract fruit flies, so increases should be made gradually. In a healthy box, worms can build large populations and consume four to six pounds of food scraps per week. About four to six months after the box has been started, the worms will have converted all of the bedding and most of the food waste into "castings" which will need to be harvested so the process can begin again.

Food waste digestors are an option for people who want to reduce the amount of food waste they produce but do not have a compost pile. These units resemble commercially produced compost bins, but differ in purpose. They are designed to accept food wastes otherwise inappropriate for composting such as meats, fish, fats, or oily food scraps. In general they are built to prevent odors from being released and prevent rodents from entering the unit. Food waste digestors are fundamentally different from worm boxes and compost piles, because the digestors do not ultimately produce a soil-enhancing product. Their purpose is to cut down on the volume of food waste generated. Food waste digestors are not a "magic hole in the ground" however, and the decomposed food residue must periodically be emptied into the trash.

Using Compost

Finished compost is dark brown, crumbly, and has an earthy odor. Small pieces of leaves or other ingredients may be visible. If the compost contains many materials that are not broken down, it is only partly decomposed. This product can be used as mulch, but adding partly decomposed compost to the soil can reduce the amount of nitrogen available to the plants. The microorganisms will continue to do the work of decomposing, but will use soil nitrogen for their own growth, restricting the nitrogen's availability to plants growing nearby.

Allow partly decomposed compost particles to break down further or separate them out before using compost on growing plants. Or, use the decomposed particles as a starter in a new pile to increase the initial decomposition rate.

Compost serves primarily as a soil conditioner, whether it's spread in a layer on the soil surface or is dug in. A garden soil regularly amended with compost is better able to hold air and water, drains more efficiently, and contains a nutrient reserve that plants can draw on. The amended soil also tends to produce plants with fewer insect and disease problems. The compost encourages a larger population of beneficial soil microorganisms, which control harmful microorganisms. It also fosters healthy plant growth, and healthy plants are better able to resist pests.

One inch thick is enough to spread on your garden beds. Compost continues to decompose, so eventually the percentage of organic matter in the soil begins to decline. In northern climates, compost is mostly decomposed after two years in the soil. In southern climates, it disappears even faster and should be replenished every year.

To bolster poor soil with little organic matter, spread 2 to 3 inches of compost over a newly dug surface. Then work the compost into the top 6 inches of earth. A garden soil that has been adequately mulched and amended periodically requires only about a ½ inch layer of compost yearly to maintain its quality.

Some people recommend late fall as a good time to spread compost over a garden bed, and cover it with winter mulch, such as chopped leaves. By spring, soil organisms will have worked the compost into the soil. Others recommend spreading compost two weeks before planting time in the spring. There is really no wrong time to spread it. The benefits remain the same.

If your supply of compost is really limited, consider side-dressing, a way to use compost sparingly by strategically placing it around certain plants or along certain rows. This is best done in late spring and early summer so that the rapidly growing plants can derive the maximum benefit from the compost.

To side-dress a plant, work the compost into the soil around the plant, starting about an inch from the stem, out to the drip line, taking care not to disturb the roots. For shallow rooted plants, leave the compost on the soil surface. A 2" layer works best when left on top.

For new lawns, a 2 to 3" layer of compost is best when planting. Once the new lawn is established, a ¼ to ½" layer yearly will maintain the quality of the soil. An existing lawn top-dressed with a ½" layer of compost every year or two will be healthier than an unamended lawn. Fall is the best time to apply the compost, although an application in early spring is almost as effective.

A compost mulch can benefit trees and shrubs just as it does other plants. Spread a ½" to 1" layer of compost on the bare soil under the tree as far as the drip line. Then cover with a 2-3" layer of some other kind of organic mulch, such as chopped leaves or pine needles. The mulch will hold the compost in place and keep it from drying out. Adding compost to the planting hole of small perennial plants is valuable, particularly perennial food plants. Annuals will also benefit from a dose of compost at planting time.

Compost is the ultimate garden fertilizer. It contains virtually all the nutrients a living plant needs and delivers them in a slow-release manner over a period of years. Compost made with a wide variety of ingredients will provide an even more nutritious meal to your growing plants.

Compost is the best material available to enliven your soil no matter where you live. Farmers around the world will testify that healthier soil grows healthier plants that naturally resist disease, insects, and other environmental pressures. Adding compost to your garden is a long-term investment - it becomes a permanent part of the soil structure, helping to feed future plantings in years to come.

Compost tea

Compost tea is more or less a liquid version of compost. You take your solid compost and process it in a Compost Tea Brewer. Some just soak it in water and let the mixture sit around for a few hours or a few days. We do not advise this, as the easiest system is to mix compost with water at a ratio between 1:5 or 1:8 (1-part compost by volume to 5-8 parts water by volume). Then, you pour the liquid through a screen, or through cheesecloth or something similar to strain out the solid material into a bucket. What you have then is compost tea. Compost tea is great, because it is a very mild, organic liquid fertilizer that provides beneficial live organisms that improve the soil where you use it. Compost Tea does not burn plants like off-the-shelf fertilizers can.

Case Studies

1. UTC Carrier Corporation

Temperature matters to WasteWise partner UTC Carrier Corporation, a manufacturer of heating and air-conditioning systems. The same is true for composting, where the quality of the finished product depends on maintaining heat within the compost pile. Perhaps the company's long experience in temperature control is one reason Carrier was able to implement a highly effective windrow composting operation at its Syracuse, New York, facility, diverting 100 tons of diverse organic wastes from the landfill and saving the company $40,000 in disposal costs in 1998.

Carrier operates a closed-loop system. Four thousand employees in 18 buildings, three large cafeterias, and two carpentry shops provide the food scraps, sawdust, and wood chips that supply the composting operation year-round. Grounds maintenance generates grass clippings, leaves, and yard trimmings for composting during the fall and summer months. The finished compost goes to meet Carrier's extensive landscaping requirements at its 3.4-million-square-foot facility.

Carrier's recycling coordinator, Angie Scafidi, attributes the company's composting success to management support and employee education, both of which were cultivated as carefully as their compost

Starting With a Plan

Carrier did its homework before jumping into composting. The company formed a research team, which visited several local correctional facilities to learn about their institutional composting programs. The team then applied what they had learned to Carrier's facilities. They studied where the company generated food scraps, where source separation should occur, and who would be responsible for collecting and emptying the containers. They also collected cafeteria food waste for several weeks to determine the amount of compostable material generated each week.

To keep the procedures simple, the team limited roles in the project to cafeteria workers and grounds crew. The group also chose the composting method that required the least labor of all the options they considered --turned windrow composting.

Armed with solid research and well-thought-out procedures, the team sold Carrier management on the program by demonstrating how composting would save the company money, enhance Carrier's corporate image, and begin a new phase of waste reduction at the facility.

Implementing Through Employee Education

To smoothly roll out the new program, Carrier conducted training classes for the grounds crew and food service workers involved. The company also distributed an informational pamphlet explaining the program to all other employees.

Carrier employees were very receptive to the program. In fact, the grounds crew was so excited about it, they posted little signs indicating where they had used the first batch of compost for tree and shrub planting. The signs read, "Compost Home Grown By Carrier."

Evaluating the Program

Adding composting to the company's reuse and recycling programs demonstrated to employees that waste reduction was a high priority for the organization. "Aside from economic savings and environmental concerns," Scafidi noted, "we wanted to show our employees that we were serious about the whole concept of waste prevention."

Carrier also showed employees that composting is a waste reduction method they can take home. In celebration of Earth Day 1998, Carrier offered employees home composting equipment and classes on composting techniques. For Earth Day 1999, Carrier offered its employees free compost, and employees took home 10 tons of it to use in their home gardens.

Carrier's program emphasizes low-cost simplicity and a sense of pride in contributing to the company's waste reduction program and wider environmental goals. With these elements in place, composting at the company shows no signs of cooling off. For more information about Carrier's composting program, contact Angie Scafidi at 315 432-6791.

Carrier's Simple but Effective Process

Carrier's composting process has four stages:

- **Separation.** Carrier collects preconsumer food scraps in 90 gallon wheeled bins located near the food preparation areas of the cafeteria. Employees know that blue collection containers are for vegetable scraps only; no grease or meat products are allowed.

- **Collection and Mixing.** The buildings and grounds crew transport the bins to the compost site each day, using a front-end loader. At the site, on a concrete pad, the food scraps are mixed with sawdust, wood chips ground from clean delivery pallets, and yard waste (when available).

- **Pile maintenance.** The grounds crew uses shovels and thermometers to combine, turn, and monitor the windrows. The temperature of the piles is taken several times a week and generally runs between 105 and 140 degrees Fahrenheit. When the piles start to cool, the grounds crew turns them to ensure the middle of the pile has adequate air, moisture, and nutrients to rekindle bacterial activity.

- **Curing.** When the temperature of the windrows no longer increases after turning, the curing stage begins. Curing takes about 30 days, after which the compost is ready for spreading on Carrier grounds.

2. King County Explores Using Compost To Aid Salmon Recovery

King County, Washington, is playing a key role in a regional effort to protect and restore salmon populations, now listed as a threatened species under the Endangered Species Act. Local water quality and wetland habitats are threatened by urban development and landscaping practices that remove or compact native soils and vegetation cover, thereby damaging their capacity to retain water and filter out pollutants. Rainwater that runs off of impervious surfaces can carry sediment, pesticides, and fertilizers into water bodies, posing a threat to aquatic life such as salmon.

According to King County organics program manager Josh Marx, the county is looking closely at using compost as another tool in its wide array of salmon recovery efforts. "The combination of a rainy climate and the quick pace of development has led to excessive runoff. When compost is added to the soil," Marx explains, "it improves the soil's water absorption and retention capabilities as well as pollutant binding properties. What's good for the soil, is good for water resources, which in turn supports fish." He added that the county plans to replenish soils with compost — especially on urban land — through best management practices and site development standards.

In the meantime, the King County Department of Natural Resources has formed an organics team, incorporating representatives from different divisions to examine opportunities to integrate various organic programs. A study is now under way to determine how best to increase the capacity of organic materials being composted. The study also will analyze different facility options for handling organic feedstocks such as yard debris, soiled paper, food and wood waste, biosolids, and agricultural waste.

3. Composting Cotton at Johnston Industries

As companies experiment with composting, some are finding ways to recover organic wastes other than food scraps and yard trimmings. In fact, some manufacturers have discovered vast quantities of compostable materials in their own manufacturing by-products. This discovery paid off for WasteWise partner Johnston Industries, a diversified fabrics manufacturer based in Columbus, Georgia, that composts more than 5,000 tons of cotton fiber and saves more than $200,000 in waste hauling and disposal costs each year.

How It All Got Started

When waste fiber output increased dramatically in 1994, Johnston began to consider composting as an alternative to spending hundreds of thousands of dollars in hauling and disposal fees. Johnston hired a consultant to research composting options and then forwarded the consultant's report and a request for a feasibility study to the Alabama Department of Environmental Management. The request was approved expeditiously and Johnston has been composting ever since.

Fiber as Food for Compost
Johnston composts fiber from a Valley, Alabama, division that buys fiber by-product from other textile manufacturing plants and cleans it for reuse in absorbent products such as cotton swabs and personal hygiene products. Only the high-quality portion of the fiber is reclaimed; therefore, this process generates 10 to 15 tons per day of waste fiber, which Johnston diverts from the waste stream into its composting program.

According to Johnston's environmental manager Hal Wood, "Measuring the amount of fiber composted is straight-forward." The difference between the amount of fiber by-product that enters the plant for processing and the amount of cleaned fiber that exits the plant to be sold is the amount of waste fiber sent for composting.

Johnston uses windrow composting to break down the fiber. Employees form piles using front-end loaders and aerate the mixture with a Wildcat compost turner. With adequate rainfall and aeration, the composting process takes 90 to 120 days.

According to Wood, "Composting at Johnston Industries is a simple process--Mother Nature takes over, but she is not very forgiving without the right moisture and oxygen content." Johnston can add moisture to the operation during dry periods in the summer, but the composting process operates more naturally and efficiently in spring, fall, and winter, when the area receives adequate rainfall.

Marketing Composted Fiber
Five years after its inception, the program is still going strong. The company sells or gives away finished compost to local gardeners and hobby farmers. Not surprisingly, the company experiences a surge in demand in the springtime, although the compost is available year-round.

As gardeners around Valley, Alabama, can attest, Johnston has turned a mountain of waste disposal costs into piles of a useful commodity. For more information about Johnston Industries' fiber composting program, contact Hal Wood at 706 641-3190.

5. Livestock Rendering

Farmers caught in the middle - between the recent federal bans against "downer" animals in the human food chain, as ordered by the United States Department of Agriculture (USDA), and the rising costs for disposing of cattle that cannot walk to slaughter - now have a practical and economical alternative, according to waste-management experts at Cornell University.

Natural rendering, also known as composting of whole animal carcasses on the farm, is economical and environmentally sound for all animals that do not show signs of neurological disease, such as bovine spongiform encephalopathy (BSE, or mad cow disease), say compost researchers who tested the technique at the Cornell Waste Management Institute.

"The heat generated by thermophilic composting, 130 -160 degrees Fahrenheit, reduces most pathogens entering the compost pile," says Jean Bonhotal, the Waste Management Institute researcher who studied natural rendering and produced a set of printed and videotaped instructions. "But we doubt that composting destroys the prions associated with mad cow disease, so we emphasize this important exception: Animals showing signs of neurological disease must be reported to authorities and disposed of in the manner they recommend."

Otherwise, livestock that are composted with the approved technique - placed on a bed of wood chips and completely covered with high-carbon material such as sawdust or silage and more wood chips - are reduced to clean bones in four to six months and to a usable soil amendment in a year. The same technique works with butcher "residuals," the 60 percent of slaughtered livestock that is not salable meat, according to Bonhotal.

"Most people don't realize that composting is a legal and acceptable way of disposing of these materials," Bonhotal says. "Composting of dead livestock can be accomplished in compliance with environmental regulations in most states," she adds.

Composting conquers whale of a problem

Here's an example of how well the process works: A 300,000-pound right whale that died off the coast of New Jersey was obtained by a museum, trucked to Ithaca and covered with horse manure. After 12 months the compost pile was opened by museum workers, who separated bones from composted soil and assembled the whale skeleton for display at the Paleontological Research Institution's Museum of the Earth.

"If natural rendering works on a 15-ton whale, it won't have a problem with a 1,200 pound steer," Bonhotal says.

Even before the December 30, 2003, order by USDA Secretary Ann Veneman banning downer cattle from the human food supply, dealing with the estimated 150,000 disabled animals a year in the United States was becoming problematic, Bonhotal notes. Sending downer cattle to rendering plants had become more costly because of declines in price and demand for hides, tallow, bone meal and other commodities produced from carcasses.

Some rendering plants closed altogether and others hiked the fees to pick up carcasses from farms, while more farmers resorted to burying carcasses in shallow pits or leaving them to decay above ground. Either of those disposal practices can endanger the health of domestic livestock, wildlife and pets, Bonhotal observes, while run-off can contaminate nearby water sources.

None of those problems should occur with a properly managed compost operation, the Cornell expert says. The finished compost can either be used as a base for the next cycle of natural rendering or can be used as a soil amendment for hay, field corn, winter wheat or tree plantations. Although it is particularly rich in the plant nutrients nitrogen (N), phosphorus (P) and potassium (K), compost from animal carcasses should not be

used to fertilize crops that will be consumed by people, the Waste Management Institute recommends.

Additional Resources

Pennsylvania Department of Environmental Protection page on how to make compost tea: http://www.dep.state.pa.us/dep/deputate/airwaste/wm/recycle/Tea/tea1.htm

NPR online article about making compost tea:
http://www.npr.org/programs/talkingplants/features/2002/compost/

Organic Gardening article on making compost tea:
http://www.simplegiftsfarm.com/Articles/Artcomp3.html

SoilSoup is the manufacturer of the compost brewer we used in our demonstration. They offer a pretty lively (if decidedly commercial) Web site (http://www.soilsoup.com/home.asp) with useful links.

The Soil Food Web (http://www.soilfoodweb.com/phpweb/) is the brainchild of microbial ecologist Elaine Ingham, author of *The Compost Tea Brewing Manual* (3rd Edition).

BBC Laboratories is another micronutrient-rich site and research lab. Love their summary guide for microbial analysis; amaze and impress your friends.

Woods End Research Laboratory is the oldest compost-testing lab in the U.S. Stop here to learn about using compost to detoxify soil (a.k.a., bioremediation). (http://www.woodsend.com/)

In the best name category, the makers of the Microb Brewer win hands down. Good links page, too. (http://www.microbbrewer.com/)

Brewmeisters
Some of these links are a bit beyond the casual home-brewer and cater to professionals, but are worth visiting if you're interested in sustainable agriculture.

Alaska Giant: John & Mary Evans provide mail-order compost kits for the home gardener. You can sample their brew at Landscape Supply in Palmer, Alaska. Honest! (http://www.alaskagiant.com/)

Compost Tea: EPM, Inc. manufactures both compost tea brewers and vermicomposting systems (remember the worms?). (http://www.composttea.com/)

Growing Solutions, Inc., another brewmaker. Need a 500-gallon tank? (http://growingsolutions.com/)

Earthworks wins the good deed award for selling compost tea machines to dozens of U.S. golf courses. (http://www.soilfirst.com/)

Cornell University Waste Management Institute: http://cwmi.css.cornell.edu/.

Linda Chalker-Scott, from the Center for Urban Horticulture in Seattle, weighs in on the myths of compost tea: http://depts.washington.edu/mulch/myths/compost_tea.pdf.