

Agricultural composting and water quality

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Composting, a controlled process for stabilization of organic matter, can turn waste into a valuable soil amendment. Creating compost from waste materials provides an opportunity to return nutrients and organic matter to the soil, a proven practice for soil quality enhancement. Compost can improve crop growth and provide environmental benefits by improving soil tilth and its capacity to absorb and hold water and plant nutrients. A properly managed composting process can destroy weed seeds, plant pathogens, and human pathogens.

This publication is designed to assist farmers in conducting efficient, cost-effective, on-farm composting that presents reduced risk to surface and groundwater quality. It was written for operators of small to medium-size on-farm composting enterprises who handle about 100 to 5,000 tons of raw organic material per year.

Most on-farm composting enterprises are now required to operate under some form of permit. The type of permit, and the details specified in it, vary depending upon the situation. Before you begin composting, understand the regulations that apply to your activities.

This publication is intended to assist farmers who are regulated by Oregon Department of Environmental Quality rules to qualify for DEQ registration permits, the simplest DEQ composting permit. Livestock operations that compost manure under a permit from the Oregon Department of Agriculture may not need a DEQ permit.

This publication is organized into six interrelated chapters. We recommend that you spend a few minutes browsing the whole publication. If you are new to composting, some of the basic compost process terms and options are outlined in Chapters 1 and 4. If you are an experienced composter, you might want to view water quality issues first.

As you read these chapters, jot down notes and ideas. These can help you develop a site plan and management strategy that will maximize the efficiency of the composting process and minimize threats to water quality.



Compost can improve soil quality and plant growth. Sunflowers in compost-amended soil (right) vs. no compost (left).

Photo: Dan Sullivan



The compost cycle

Photo: Dan Sullivan

Chapter 1: On-farm composting: What you need to know

Composting on the farm is an enterprise. This chapter discusses two important aspects of enterprise development: the potential value of compost, and regulatory considerations.

The value of composting

Composting waste from crops or livestock reduces the volume of the material, converting it from a potential problem into a valuable resource. Crop farmers value compost as an amendment for field soil or as an ingredient in potting mix. Livestock operations can turn manure into a value-added product such as bedding or a soil amendment. When applied to the soil, compost can:

- Improve soil physical properties like water infiltration, aggregate stability, and water-holding capacity
- Improve soil chemical properties like nutrient content and cation exchange capacity
- Improve soil biological properties like disease suppression and nutrient cycling

Making your own compost gives you control over feedstock. You also have control over the quality of the finished compost, such as its maturity, stability, weed seed and human pathogen content, nutrient and salt content, particle size, and herbicide residues.

Making your own compost may save money as well. Some farmers compost feedstock from their own farms and other nearby sources, using relatively lowcost methods to produce a valuable product. It's always recommended that you compare that cost to the ultimate value of the crops you produce.

Rules for Oregon composting facilities

Composting is the managed biological decomposition of feedstock that includes but is not limited to reducing particle size, adding moisture, manipulating piles, and performing procedures to achieve human pathogen reduction.

Leachate is any water that has come into contact with compost or feedstock. Leachate can easily contaminate surface or groundwater and may pose risks to health and the environment.

The Oregon DEQ implemented composting rules in September 2009 that establish environmental performance standards and permit requirements for composting facilities. DEQ's goal is to promote composting while protecting public health and the environment, including water quality. You will find the complete rules on the DEQ website "Composting Program Policy and Composting Facility Rules" (see "References and Resources").



Composting waste from crops or livestock reduces the volume of the material, converting it from a potential problem into a valuable resource.

Photo: Dan Sullivan



Seasonal runoff.

Photo: Dan Sullivan

All non-CAFO operations (concentrated animal feeding operations) that compost 100 tons or more of feedstock per year, or more than 20 tons of animal carcasses or meat waste per year, must submit screening information and a Land Use Compatibility Statement to DEQ to apply for a composting permit. A Land Use Compatibility Statement is a document signed by a city or county planner after a period of public comment. DEQ reviews the application, conducts a site visit, and evaluates the level of environmental risk posed by the composting site. During the screening process, DEQ staff can help identify ways to minimize environmental risk.

Low-risk sites are issued a simple **registration permit**. These facilities must follow their composting plan and meet environmental standards. They must also notify DEQ of any changes to the plan.

If DEQ determines that your site poses greater environmental risk, you may be required to submit a site operations plan as a step toward receiving a **composting permit**. If you are required to develop permanent infrastructure at your composting site to protect the environment, seek professional guidance if needed. This publication does not address the technical details involved in designing composting pads, roofs, or leachate collection and treatment systems.

If you apply for a composting facility environmental risk screening, you may wish to review your plans with DEQ staff before you develop or modify your site. See [detailed information about the DEQ rules](https://www.oregon.gov/deq/Regulations/Pages/default.aspx) (<https://www.oregon.gov/deq/Regulations/Pages/default.aspx>).

Chapter 2: Site selection

Thoughtful site selection will minimize your composting operation's risk to surface and groundwater. It reduces the need for expensive infrastructure and improves process efficiency. When choosing a site for your on-farm composting operation, consider the following:

- Whether the site will operate seasonally or year-round
- The volume of materials to be processed, cured, and stored, and the space available for these activities
- Capacity of the site to support equipment traffic during the rainy season
- Depth of the seasonal high water table
- Proximity to drinking water wells and septic systems
- Topography of the site and its distance from surface water, including ditches, wells, and tile drains

Site infrastructure

Dedicated composting areas should be large enough to stockpile feedstock; blend, build, and manage actively composting piles; and store compost while it is curing and until use. The composting method you choose dictates the size of your site and whether it needs surface improvement, electricity, access for equipment and a water source. See Chapter 4 for more detail on the requirements for the various composting methods.

The availability of feedstock and the need for storage before composting will clarify some requirements for site infrastructure. For example:

- Livestock operations produce manure year round. Most raw manure requires covered storage or a year-round site for continuous composting.
- Food waste and yard debris rich with grass clippings require immediate incorporation into bulking materials to avoid problems with odors, rodents, and flies.

Choose a site with surface soil that is firm enough to support heavy equipment during periods of high use.

When you choose your site, be a good neighbor and reduce the potential for complaints. Use distance, trees, and existing buildings as buffers to keep noise, dust, and odors from neighboring properties.

Specialists at Oregon DEQ can assist you in choosing likely composting sites on your property, and advise you on the merits of one site over another to minimize water quality impacts.

Site features and management practices affecting water quality

Soil

The nature of the soils and geologic strata beneath your composting site determines the risk to groundwater and neighboring wells. Soils differ in many characteristics that control infiltration, drainage, and runoff. The NRCS Web Soil Survey provides general information about the soils beneath your site and what these soil characteristics mean for water movement. DEQ specialists will evaluate geologic strata underlying the site for their potential to allow leachate to reach groundwater.

Exposed feedstock

Raw feedstock exposed to wet weather can lead to surface or groundwater contamination. These materials and wet feedstock must be quickly combined with dry, high-carbon material to reduce leachate, odor, and fly problems. See Table 6 for the relative water quality risk of contrasting feedstock.

In general, the risk of nutrients and pathogens reaching water is reduced during the dry season.



Roofed composting area.

Photo: Dan Sullivan



Even on well-drained soils, compaction can make the site unusable in midwinter.

Photo: Dan Sullivan

Proximity to surface water

There is no fixed distance-to-surface-water rule, but farther—100 feet or more—is usually better. See Chapter 6 for information on berms, filter strips, and other techniques, and their roles in protecting water quality.

Plug tile drains under or adjacent to the compost site to prevent transfer of runoff and leachate to surface water. Convert unvegetated drainage ditches to grassy swales.

Topography

Moderate slopes reduce pooling. Excessive slopes accelerate the rate at which water leaves the site and may promote erosion. Choose a site with a gentle slope, or grade a steeper site to a 1- to 2-percent slope to avoid erosion.

Site management

During site construction, take measures to prevent erosion and runoff. Common strategies include building silt fences and filter berms and re-establishing grass or other soil-retaining vegetation soon after construction.

Consider how you may use the site after the composting operation ends. Remediating compaction from heavy equipment may require extra effort.

See Chapter 6 for more information.

Keep these guidelines in mind when you choose your site

- Consider space requirements, and accessibility and availability of electricity and water.
- Choose a site with surface soil that is dry and firm enough during the dry season to support heavy equipment during periods of high use.
- Minimize leachate potential by composting as much as possible during the dry season and managing water additions. Locate compost sites as far as possible from wells, drainage ditches, and surface water. Plug tile drains. Avoid sites with high seasonal water tables.
- A gentle slope and permanent grass filter strips reduce the risk of erosion.

Chapter 3: Compost site layout and design

Thoughtful site layout and design promote the efficient production of quality compost and protect water quality. This chapter covers the characteristics of good composting sites, how to estimate the area required, and how to organize your site so that the work process flows smoothly. Be sure to choose your site and plan the layout and workflow before you collect any feedstock or begin composting.

Here we focus on site designs that do not require permanent structures. Temporary sites that will be returned to farming within a few years are designed differently than permanent sites. If your site requires permanent structures, seek professional guidance (as from a consulting engineer) if needed.

We recommend that you sketch your site and then stake it out before beginning construction.

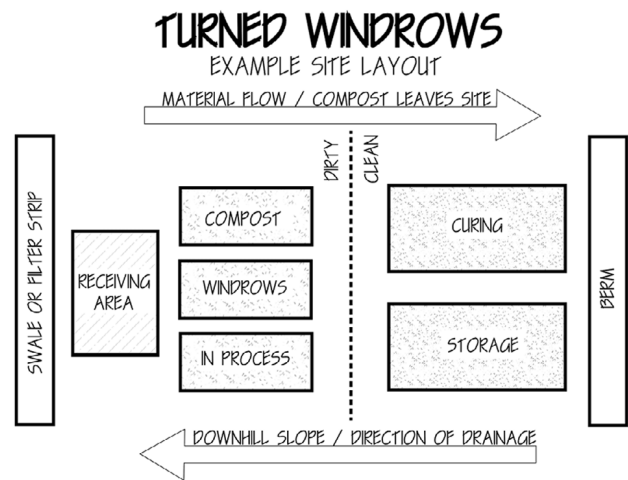
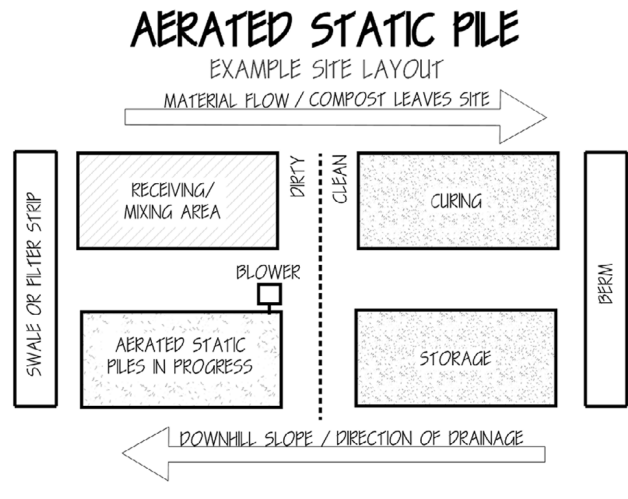


Figure 1. Concepts for site design.

Photo: Dan Sullivan

Site layout

Plan the site so that material is easily handled and moved through the composting process. Adjust the length of piles and space between piles to minimize movement of materials. This approach maximizes the volume of compost produced per square foot of the site. Add the areas required for each phase and activity of the composting process to determine the total area for your operation.

Figure 1 shows a typical site layout for two types of composting operations. Use these illustrations as a general guide when planning the layout of your compost site. Note the movement of materials across the site. Notice that finished and stored compost occupy the higher side of the site, and feedstock is received at the lower side. This prevents the finished compost from being contaminated by materials with higher pathogen content. (The dashed line divides the clean side from the dirty side.) If possible, select a site with a slope that follows the prevailing wind direction. This will minimize the spread of pathogens by wind and water within the production area.

Berms placed upslope from large piles divert water away from them. The illustrations show typical placement of berms to direct surface flows away from the composting site and swales or filter strips to filter or direct flows

downstream from the composting site. See Chapter 6 for more ideas and information.

Compute the size of your composting area

First, determine the volume of feedstock at peak times. Then, estimate the footprint of the receiving and mixing area, and of the active composting, curing, and storage areas. Finally, allow enough space between areas to manage the compost and maintain the site. Use Table 1 to calculate the footprint of the compost windrow. Pile volume and footprint vary with the shape of the pile. Table 1 assumes a compost windrow with a rounded top to be turned with a front-end loader. The On-Farm Composting Handbook (see “References and resources”) contains formulas and tables to help you calculate the footprint of other pile profiles.

Table 1. Calculate the footprint of a turned compost pile

Line	Calculation	Formula	Example	Your pile
1	Volume of compost		200 yd ³	
2	Width of the base (yd)		4 yards	
3	Pile height (yd)		2 yards	
4	Area of cross section (yd ²)	$2/3 \times \text{width} \times \text{height}$	$2 \times 4 \times 2/3 = 5 \frac{1}{3} \text{ yd}^2$	
5	Pile length (yd)	volume \div cross section; Line 1 \div Line 4	$200 \div 5 \frac{1}{3} = 37 \frac{1}{2} \text{ yd}$	
6	Area of footprint (yd ²)	width \times length; Line 2 \times Line 5	$4 \times 37 \frac{1}{2} = 150 \text{ yd}$	

Table 1 assumes you have an estimate of the volume of feed stock you will compost. You can adjust the measurements for the width of the base and the height of the pile to try out various site configurations.

Active composting reduces pile volume as carbon dioxide is released, particle size is reduced, and the pile settles. The amount of reduction depends on the type of feedstock. Plant materials reduce more than manure, which reduces more than wood products or soil. A rough guide to reduction might be that curing piles are about 55 percent of the original feedstock volume and finished compost is about 45 percent. Curing and storage piles can be as high as 12 to 18 feet, limited only by the lifting capacity of the loader or excavator. For piles to be at least 3 feet high after a month of active composting, build them higher than 3 feet initially.

In your plan, allow room for alleyways and pile edges. Driving on the edge of a pile creates undesirable compaction of the compost. Consider whether more than one piece of equipment may be operating at the same time. If so, allow enough space so that vehicles can pass. Windrow turners require 25 to 45 feet to turn at the end of each row. Allow enough room between piles to maneuver your tractor for front-end loader turned piles. See Chapter 4 for more detail on pile turning methods.

Combine small compost piles whenever possible. Their high surface-to-volume ratio and low water-holding capacity can generate high volumes of leachate.

Infrastructure for high-risk feedstock

There are several strategies for handling high-risk feedstock with the goal of protecting water quality. Each strategy has advantage and limitations. From most expensive to least expensive, options include:

- Build a feedstock handling facility with a roof and composting pad.
- Build a roof without a pad or a pad without a roof.
- Cover feedstock with a tarp.
- Store feedstock, such as deep bedded litter, in the barn until you actively compost it.
- Receive high-risk feedstock from off the farm only during the dry season.

High-risk feedstock that is exposed to wet weather can lead to surface or groundwater contamination. Some high-risk feedstock, such as food waste or livestock mortalities, is not amenable to storage and must be composted immediately. See Table 6 for a comparison of feedstock and water quality risk.

Impermeable pads do not prevent leachate generation, but they can allow you to collect, store, and use this liquid appropriately. Compost pads allow material handling during wet weather, though they can be expensive. They limit infiltration of air and water into the soil, change the soil's microbial community, and prevent you from using the site for other purposes.

Covers prevent storm water from coming into contact with high-risk-feedstock and can prevent leachate generation. Well-managed, active compost piles often generate enough heat to evaporate excess moisture and reduce the need for covers.

Keep these guidelines in mind when you design and lay out your site

Site layout

- Choose a site with a gentle slope, or grade a 1% to 2% slope to avoid puddles or erosion. Orient piles parallel to the slope to minimize leachate production during high rainfall seasons.
- Place curing and storage piles at the top of the slope, with active composting areas just below, and feedstock receiving areas at the bottom. Runoff from curing and storage areas is generally much cleaner than runoff from the receiving and active composting areas.
- Choose a site 100 feet or more from waterways, ditches, wells or septic fields.
- Install a berm or grassy swale downslope from the receiving area.

Site size

- Feedstock availability and quantity dictate in part how much area you must devote to composting. Estimate the volume of material you plan to handle, and calculate the area needed for feedstock, active composting, and curing piles.
- Make feedstock collection and handling areas as small as practical. Smaller areas force timely management of fresh feedstock and reduce the area to be cleaned and maintained.
- Combine small piles to minimize the area under cover. Small, unmanaged quantities of feedstock or compost can generate large volumes of leachate.
- Reserve uncovered storage space for bulking agents and very stable feedstock, such as leaves or straw.
- Work high-risk feedstock into bulking agents immediately upon arrival at your site; never store them.
- Plan a storage area for finished compost that can accommodate compost production sufficient for farm needs.

Site maintenance

- Create a layout that allows smooth movement of material and equipment through the site and minimizes leachate generation.
- Sod in alleyways may improve traction and reduce runoff. Mow the grass periodically during the growing season and compost it.
- Allow room to keep alleyways and areas near the piles clean. Small mounds of compost and the edges of piles have low water-holding capacity and can generate high volumes of leachate.
- Consider whether there may be more than one piece of equipment operating at the same time. If so, be sure access areas are wide enough to allow vehicles to pass.
- Allow enough space to maneuver equipment without compacting the edges of compost piles.



Sod may improve traction in alleyways.

Photo: Nick Andrews

Chapter 4: Choose the composting method that's right for you

Choose a composting method that suits your farm, your feedstock, and your goals. Consider the characteristics you want in the finished compost and the equipment available to you. Manage your composting operation to meet the needs of your farm while protecting water quality.

Composting operations tend to evolve over time according to the manager's experience, the scale of the operation, and opportunities to reduce cost. The most common methods of on-farm composting are **turned windrows** and **aerated static piles**. They differ in aeration management.

Turned windrows

Compost managed as turned windrows is aerated by physically moving the composting feedstock. Turning a pile reduces particle size and breaks apart clumps of feedstock which can otherwise become anaerobic. Turning increases oxygen levels in the pile for a short time and provides a good opportunity to adjust pile moisture content and further mix materials. Common equipment for turning windrows includes front-end loaders and windrow turners.

Turning with a front-end loader

A front-end loader is a common piece of farm equipment that you may already own. It provides a convenient way to proportion and mix feedstock. Three to five turns may be required for adequate mixing. This is a slower process than other forms of mixing and requires more area per unit of feedstock. See Tables 2, 3 and 4 in this chapter for design limits and opportunities associated with using a front-end loader to turn piles.

An adaptation of this method turns compost with front-end loader and a manure spreader. Although two tractors are required, it is a very effective method to build and turn compost windrows. The manure spreader is attached to one tractor and the front-end loader is attached to the other. The front-end loader loads feedstock into the manure spreader. As the spreader gradually moves forward, the feedstock is spun out, creating a windrow. The same technique is used to turn the windrow. A hose-fed metal water pipe with spray nozzles installed along its length can be added to the back of the manure spreader to apply water while turning compost.

Turning with a windrow turner

A windrow turner is a piece of specialty equipment that enhances compost homogeneity and simplifies adding water. You'll need a front-end loader to proportion feedstock and shape the windrows so that they fit within the turner's capacity. The tractor that pulls the windrow turner must have creeper gears. Self-propelled units are available.

Use the turner to mix and water the pile during the first 1 to 2 months. Base turning decisions on pile temperature and moisture levels; add water as needed during turning. In a typical turning schedule, you would turn weekly for the first month, and once or twice more after that as the pile begins to cool. Turning without watering reduces moisture content, which may or may not be desirable. If adding more water is not an option, conserve moisture levels by building larger piles and turning them less frequently.

Combine windrows as they shrink and stockpile them into curing or storage piles when they are finished. Because turning costs time and money, many on-farm composters seek to minimize this activity. See tables 2, 3 and 4 for design limits and opportunities associated with windrow turners.



Front-end loader.

Photo: Nick Andrews



Windrow turner.

Photo: Nick Andrews

Aerated static piles

Aerated static piles are aerated with an electric blower connected to a network of aeration pipes. The air flows through the compost, maintaining aerobic conditions throughout the pile. ASPs are turned much less frequently than turned windrows, and generally not at all during the first 30 days of composting.

Place a layer of coarse woodchips or other porous material over the pipes to allow even distribution of air at the base of the pile. Then proportion and mix feedstock and shape piles using a front-end loader. After 1 month, remix the pile with a loader, adding water if needed. Feedstocks that reheat or generate odors after re-wetting are not yet completely composted.

Blowers can be plumbed to push air through the pile, pull air from the pile, or alternate air flow direction. Cycle timers often are used to operate the blowers at desired intervals.

Pulling air from the pile reduces moisture and helps manage odor, but it generates significant condensate that must be removed with a trap and treated as leachate. This condensate is corrosive, so blowers may require more frequent maintenance. Ideally, freshly-built piles are covered with a 6- to 12-inch layer of clean woody feedstock or finished compost. See Chapter 5 for more detail.

For highly engineered systems, seek professional guidance to correctly calculate pipe diameter-to-length ratio and the number and size of orifices and pump capacity. On a less complex system, with careful attention, trial and error may suffice. See Tables 2, 3 and 4 for design limits and opportunities associated with aerated static piles.

Comparison of composting methods

As you consider the composting opportunities, needs and goals for your farm, use the following tables to determine the right method for you. These tables offer comparisons of overall performance, space requirements and management tasks for windrows turned with a front-end loader or with a windrow turner, and for aerated static piles.

Table 2. Composting methods: compare overall performance

Method	Cost	PFRP ¹	Time to finished compost
Windrow-front-end loader	Minimal added investment	May not consistently meet PFRP with infrequent turning	6-12 months
Windrow-windrow turner	Specialty equipment	Routinely meets PFRP in 15 days with 5+ turns	2-6 months
Aerated static pile (ASP)	Engineering, design consultation advisable	Routinely meets PFRP in 3 days	2-4 months. Usually ASP for 2+ weeks, until temperature drops. Then, curing for 1-3 months.

¹PFRP is a composting process that meets prescribed conditions for human pathogen control.



Blowers can be plumbed to push air through the pile, pull air from the pile, or alternate air flow direction.

Photo: Nick Andrews

Table 3. Composting methods: compare space requirements

Method	Space	Height	Width	Distance between piles
Windrow-front-end loader	Largest site	5-8 ft	Base: 12-18 feet	Aisles wide enough for bucket loader and other equipment.
Windrow-windrow turner	Intermediate	Dictated by turner height	Dictated by turner width	Depends on turner. Self-propelled units allow narrow alleyways. Wider aisles are required for tractor-mounted units. Aisle clean-up may be hand labor.
Aerated static pile (ASP)	Smallest site for active (hot) composting. Same area needed for curing as with other methods.	8-12 feet	Dictated by pipe and blower capacity	Saves space because PFRP is rapidly met and active composting area is reused more often. Compost can be put into larger curing piles after about a month.

Table 4. Composting methods: compare management tasks

Method	Feedstock mixing	Turning frequency	Adding water
Windrow-front-end loader	Materials must be well mixed prior to forming windrows.	Usually turned two or three times.	Hard to do when turning.
Windrow-windrow turner	Turning provides additional mixing. Turning usually reduces particle size and porosity.	Usually turned more than four times during active composting, and several times during curing.	Most turners can be equipped with a water supply hose to wet feedstock when turning.
Aerated static pile (ASP)	Feedstock must be well mixed and raised to the proper moisture level before the ASP is formed.	Mix when ASP is taken down and moved to curing site.	Cannot add water after ASP is formed. Can add water when moving compost to curing site. Forced air movement through ASP increases rate of water loss.

What is PFRP?

PFRP stands for a “process to further reduce pathogens.” The U.S. Environmental Protection Agency developed standards for PFRPs to reduce human pathogens in biosolids, including *E. coli O157:H7*, *Salmonella*, *Staphylococcus*, *Bacillus*, *Clostridium*, *Listeria*, roundworms, and tapeworms. These pathogens originate in manure and other animal byproducts.

In its composting rules, the Oregon DEQ adopted the EPA’s time and temperature requirements (PFRPs) for commercial composting facilities. Commercial composters must meet PFRP before selling compost. Organic growers who include manure feedstock and apply compost less than 90 to 120 days before harvest must also meet these PFRPs, if crops are for human consumption. Commonly used PFRPs include:

- Windrows: Compost temperatures must be measured at or above 55°C (131°F) for at least three days, between each of five consecutive turning events.
- Static aerated piles with an insulation cover must reach 55°C (131°F) for three days.

Microbial studies have found that compost managed in windrows may leave viable pathogens in compost, even when PFRP has been met. This occurs because the cooler outer layers of the pile have not reached required temperatures when the internal temperature reading is at or above 55°C or 131°F. Pay careful attention to time, temperature, turning, and moisture levels.

Keep these guidelines in mind for all composting methods.

- Evenly shaped windrows have fewer dry spots and process more evenly.
- Plan ahead. Keep piles slightly drier before and during seasonal rains and wetter just before and during seasonal dry periods.
- Direct flowing water away from the edges of the piles and reduce leachate generation.

Compost, food safety and good agricultural practices

Compost use is one of many topics for self-assessment in the [National Good Agricultural Practices food safety program](https://cals.cornell.edu/national-good-agricultural-practices-program) (<https://cals.cornell.edu/national-good-agricultural-practices-program>). The program's materials include some questions of importance for composters who apply compost to food crops or sell compost to farmers who do so. For composters, the goal of this program is to ensure that PFRP has been met, and that the compost has not been cross-contaminated after meeting PFRP.

Curing piles must be moistened with clean water. Usually, well water has fewer pathogens than surface water. Leachate from fresh compost piles usually has a high pathogen content. If this leachate is applied to compost at any stage of processing, PFRP must be met after its application.

Food Safety Modernization Act requirements for composting are similar to those mandated for compost in the USDA-Organic rule. Windrow or aerated static pile composting methods are allowed. They must meet prescribed time and temperature conditions, followed by adequate compost curing. Check current FSMA rules at the [FDA](https://www.fda.gov/food/food-safety-modernization-act-fsma/fsma-rules-guidance-industry) (<https://www.fda.gov/food/food-safety-modernization-act-fsma/fsma-rules-guidance-industry>).

Chapter 5: The composting process and its impact on water quality

The practices that protect water quality also contribute to the production of high quality compost. Composting proceeds efficiently when there is adequate moisture and porosity, and a good carbon-to-nitrogen ratio.

Carbon and nitrogen

Think of compost feedstock as a food supply for decomposer bacteria and fungi. For humans, a quality diet is expressed as recommended daily allowances. For decomposer organisms, a quality diet is expressed as carbon-to-nitrogen ratio (C:N). With a balanced C:N, decomposer organisms efficiently consume the available nutrients and leave less nitrogen to escape into the environment.

The process of balancing the C:N of your available feedstock is like formulating a recipe. Starting with the right mix of carbon to nitrogen can contribute to an efficient composting process and quality compost. Consider whether the feedstock available on your farm requires supplemental feedstock to compost well. If it does, look for nearby feedstock that will provide the C or N you need. Many materials compost well without additional feedstock.

Mixtures of feedstock with 20 to 40 parts carbon to one part nitrogen (20:1 to 40:1) compost well. The WSU Compost Mix Calculator provides typical values for the C:N ratio of feedstock and calculates the C:N ratio of different feedstock combinations. Well-mixed piles use nitrogen efficiently, decompose feedstock quickly, and heat up enough to reduce plant and human pathogens and kill weed seeds. Agricultural testing laboratories can provide an analysis of C:N as well as other nutrients, permitting you to optimize feedstock mixtures. See the sidebar for a summary of National Organic Program standards for compost.

Feedstock that contains more nitrogen than decomposers can use releases nitrogen as ammonia gas (NH_3) or as soluble nitrate (NO_3). Released nitrogen reduces air and water quality and wastes valuable plant nutrients. With too little nitrogen, much of the carbon goes undigested, and the compost pile may not heat up enough to kill weed seeds and pathogens. See the sidebar about processes to further reduce pathogens (PFRP).

The molecular form of carbon-rich material influences its susceptibility to decomposition. Fresh, soft, green leaves, fruits, and processed grains contain carbon in the form of simple sugars. Bacteria readily digest these materials, often within two to 10 days. This form of carbon is called *available carbon*. Straw, stems, hulls, bark, and wood are made of cellulose, hemi-cellulose and lignin. These complex carbons are more resistant to decomposition. In active compost piles, many of these materials will decompose fairly quickly, but larger wood particles do not. Under dry conditions, fungi decompose woody structures over months or years.

Water quality risks of contrasting feedstocks

Feedstock with higher nutrient content, lower C:N, or more pathogens poses greater risk to water quality than other feedstock. High-risk feedstock is more likely to require covers and pads or other infrastructure than low-risk feedstock. Table 6 rates the relative environmental risk of common feedstock.

Use caution and experiment on a small scale with higher risk feedstock, until you understand how to manage it properly.

Compost moisture content

Correct moisture content is the most important variable in compost management. Without enough water, even feedstock mixtures with ideal C:N will not compost efficiently. All compost piles develop dry spots over time. Thorough turning redistributes moisture.

A thin layer of moisture on particles of organic matter is essential for microbes to move and multiply. Excess water can prevent heating and limits the action of more efficient oxygen-breathing (aerobic) bacteria, leaving the pile wet and cold. Under these conditions, composting slows significantly and pathogens may survive in finished compost.

Water holds five times as much heat per gram as compost. Heat is transferred when water evaporates and condenses in a compost pile. When water evaporates in hot spots, heat energy is stored in the water vapor. The water vapor condenses after rising into cooler spots. During condensation, energy is released and can warm the

compost. High-energy feedstock that readily generates heat can lose moisture rapidly as compost heats up. Moisture content below 40% by weight severely limits composting. After moisture is provided, dry piles often reheat and further the composting process.

If your feedstock is too dry or wet, look for supplemental feedstock to increase or decrease the moisture content of the pile. If needed, add water as you build a compost pile, and then adjust moisture as you turn it. Generally, a moisture content of 60 to 65 percent is ideal during the first two to three weeks of composting. As composting nears completion, consider allowing compost to dry enough for your intended use. For livestock bedding or screening (i.e., for potting soil), drier compost is normally preferred (40% to 45% moisture). For field application, avoid dusty or saturated compost and aim for 45% to 55% moisture.

Weather and moisture content

Use the weather to your advantage to maintain correct moisture levels. Changes in wind speed, relative humidity, and ambient temperature affect the rate of moisture loss. When the weather is very hot, actively composting piles can lose as much as 2% or 3% of their moisture per day. Under these conditions, moisture could decline from 60 percent to 40 percent — too dry to compost — in one week. Taller piles tend to conserve moisture.

Maintain moisture at recommended levels. Piles with too much moisture lack sufficient oxygen to support hot, aerobic decomposition, are prone to developing objectionable odors, and may not reach temperature targets. These anaerobic conditions are common with low-energy, uncovered piles in the wet season. Piles that are too dry will not sustain active composting. Manage your compost at optimum moisture ranges to avoid a host of problems, including leachate generation.

Tracking the temperature and moisture content of fresh compost piles through the seasons will sharpen your “composting sense” and support your decisions about when and how to turn or cover your piles relative to weather conditions.

Testing for moisture content

The following methods measure compost pile moisture accurately and consistently.

Hand squeeze test

You can develop the ability to estimate a compost pile’s moisture level using the “hand-squeeze” test. With practice, and confirming your estimates with the drying test, your hand becomes “calibrated.” This method is fast and useful, but you must practice and compare with results from oven drying.

Reach into the pile and grab a handful of composting material. Observe your fist while squeezing the material firmly. Release your grip, palm up, and observe the material and your hand. Scan the list of observations in Table 5 and estimate your moisture content.

Table 5. Hand squeeze test observation key

Observation	% moisture
Material is crumbly; doesn’t stick together; feels dusty; glove is dry	42 or less
Material feels mostly dry but has a hint of moisture in it	42 to 47

Observation	% moisture
Material feels tacky	47 to 52
Material feels moist	52 to 58
Material sticks together; glove glistens or has a wet sheen	58 to 63
Squeezing releases one to two drops of water	63 to 68
Squeezing releases many drops of water	68 to 73
Squeezing releases a stream of water or material has a pudding texture	> 73

Fine-textured materials can give accurate estimates. Coarse-textured materials result in low moisture estimates. Adjust upwards by as much as 4%. Table used with permission of Jeff Gage, Compost Design Services.

Drying test

You can accurately determine the moisture content of a compost sample by weighing it, then drying it with a silage (or similar) dryer. You can use oven or even sun drying if dryers are not available. Weigh and dry the compost repeatedly until the sample loses no additional weight. A reasonable temperature for drying compost is 110°F to 140°F. Enter your wet and dry weights into this equation to calculate the percent moisture:

- $[(\text{wet weight} - \text{dry weight}) \div \text{wet weight}] \times 100 = \% \text{ moisture}$

The WSU Compost Mix Calculator can help you estimate the amount of water needed to establish good moisture content when mixing a pile.

Be aware that drying compost or soil with in-home appliances may result in objectionable odors.

Herbicides in feedstock

It can be difficult to know whether feedstock originating off-farm has been exposed to herbicides that can persist through the composting process. Compost contaminated with some pyridine herbicides such as chloropyralid and aminopyralid can harm sensitive plants. These materials are active in compost at low concentrations.

The herbicide labels indicate that the feedstock provider must warn you at the time of transfer that persistent pesticides have been used on the feedstock. Often, this is not done. If feedstock changes hands through a middleman or hauler, that person may not know. Washington State University Extension Service offers a [simple bioassay for persistent herbicides](https://s3.wp.wsu.edu/uploads/sites/411/2014/12/PDF_Clopyralid_Bioassay.pdf) (https://s3.wp.wsu.edu/uploads/sites/411/2014/12/PDF_Clopyralid_Bioassay.pdf).

Aside from pesticides, you could bring disease or weed seeds onto your property in feedstock originating off-farm. The best way to avoid these problems is to talk to the feedstock provider about the source of materials, pesticide applications, and other contaminant risks.

Porosity and bulk density

Porosity is a measure of the free air space between compost particles. The more a feedstock weighs per unit volume, the less free air there is between its particles. **Bulk density** measures the weight per unit volume of a material. It is inversely related to porosity. The higher the porosity, the lower the bulk density.

An ideal feedstock balances porosity and density, and usually requires less frequent turning to maintain working temperatures. Feedstock porosity influences management of the composting process. High porosity promotes airflow through the pile, which in turn cools it and replenishes the oxygen supply. Because of their capacity to lose water, highly porous mixtures may require more careful moisture content monitoring.

Dense, low porosity feedstock requires more frequent turning or greater air pressure to ensure adequate airflow. Detailed directions for measuring porosity and bulk density are included in the WSU Compost Mix Calculator.

Be aware that drying compost or soil with in-home appliances may result in objectionable odors.

WSU Compost Mix Calculator

To determine your feedstock recipe, see Washington State University's Compost Mix Calculator, available for download on their [Organic Farming Systems and Nutrient Management website \(https://puyallup.wsu.edu/soils/compost-mix-calculator/\)](https://puyallup.wsu.edu/soils/compost-mix-calculator/). The calculator is an Excel file with six worksheets: a list of feedstock characteristics, a worksheet on which you enter your feedstock characteristics and their proportions in a proposed mix, a sheet that calculates C:N ratio and water needs of the proposed recipe, and sheets that calculate bulk density and free air space (porosity). Use the Calculator to optimize your compost recipe based on available feedstock, and to calculate bulk density and porosity. In calculations for C:N, ignore woody particles over ½ inch thick. These increase porosity and maintain airflow but provide little available carbon.

What do the National Organic Program standards say about compost?

From [§205.203, Soil fertility and crop nutrient management practice standard \(https://www.ecfr.gov/current/title-7/subtitle-B/chapter-I/subchapter-M/part-205\)](https://www.ecfr.gov/current/title-7/subtitle-B/chapter-I/subchapter-M/part-205).

- (C) The producer must manage plant and animal materials to maintain or improve soil organic matter content in a manner that does not contribute to contamination of crops, soil, or water by plant nutrients, pathogenic organisms, heavy metals, or residues of prohibited substances. Animal and plant materials include:
 - (2) Composted plant and animal materials produced through a process that:
 - (i) Established an initial C:N ratio of between 25:1 and 40:1; and
 - (ii) Maintained a temperature of between 131°F and 170°F for 3 days using an in-vessel or static aerated pile system; or
 - (iii) Maintained a temperature of between 131°F and 170°F for 15 days using a windrow composting system, during which period, the materials must be turned a minimum of five times.
 - (3) Uncomposted plant materials.

The National Organic Standards Board Compost Task Force final report includes the following policy statement that is used for guidance, but is subject to change as needed by the USDA:

- Compost, in addition to that described in section 205.203(c)(2), is acceptable if (i) made from only allowed feedstock materials, except for incidental residues that will not lead to contamination, (ii) the compost undergoes an increase in temperature to at least 131°F (55°C) and remains there for a minimum of 3 days, and (iii) the compost pile is mixed or managed to ensure that all of the feedstock heats to the minimum temperature.

Equipment maintenance

When turning or managing your piles, begin with the more processed material (i.e., curing piles) before moving on to less processed, active piles and raw feedstock. Equipment can easily re-contaminate curing compost with pathogens. After handling feedstock or active piles that have not gone through PFRP, thoroughly clean equipment with a pressure washer before handling cured compost. Maintain your equipment so that fuels and lubricants do not contaminate your compost.

Covering piles

Most compost piles in the hot, active phase of composting won't require covering. Lower-risk feedstock, such as leaves and ground woody yard debris, may not require covering until the curing phase. Carefully monitor a cooling or curing pile and cover it before it becomes saturated and generates leachate. Covered compost is less likely to be re-inoculated with weed seeds or pathogens from stray animals and wildlife, or become too wet for easy use.

The following factors influence how much and how quickly moisture levels increase and leachate can appear:

- **Composting stage.** Fresh, energetic feedstock mixtures are likely to generate enough heat to drive off excess water. More mature piles are less likely to do so. Curing or storage piles may need covering in wet weather. After the end of the active composting phase, curing takes an additional 30 to 60 days.
- **Shape of the pile.** Tall piles with narrow tops and steep sides catch less rainfall and shed rain more easily. Short piles with flatter sides catch more rainfall and shed less rain. Taller curing and storage piles retain moisture and can be covered with smaller tarps. With experience, you can manipulate pile shape to manage moisture content.
- **Clean pile edges.** Compacted soil mixed with compost can quickly generate large amounts of leachate when saturated.

How to cover

Choose one of these methods:

- **Tarp.** Position weighted or tied tarps over the pile so that it sheds water. Tarps must be secured against high winds. While tarping is not recommended for actively composting feedstock, finished compost can be tarped without negative effects.
- **Build a roof.** Actively composting feedstock will benefit from the increased airflow that a roof permits. A roof permits you to easily maintain optimum composting conditions and avoid leachate.
- **Mulch.** Aerated static piles may be covered with a 6- to 12-inch layer of fine, finished compost, sawdust, or other pathogen-free material. However, a mulch cover can be difficult to apply and can require a considerable volume of mulch. This cover layer serves several purposes:
 - Retains heat and ensures that all raw materials meet criteria for pathogen destruction (PFRP)
 - Reduces odors
 - Retains nitrogen and moisture

- Reduces access for birds, rodents, and flies

Keep these guidelines in mind when building windrows and during the composting process

- A well-mixed compost recipe with good C:N ratio, moisture content and porosity will decompose efficiently.
- Build and maintain piles that are large enough to retain moisture during dry weather and absorb moisture without becoming saturated during wet weather.
- Monitor moisture content and adjust as needed when turning.
- Mix and turn energetic or wet feedstock into an active compost pile soon after delivery to avoid strong odors, rodents and large fly populations.
- Cover piles as needed to protect them from heavy rainfall.
- Control the direction of airflow in aerated static piles to manage moisture content.
- During a slow season, section off unused areas and sweep or scrape them clean. Divert surface water away from these areas.
- Water trucks or irrigation lines are a common way to provide sufficient water when and where it is needed.
- Make sure that the compost is protected from contamination from fueling stations or pesticide mixing areas. If you use compost in filter berms to absorb such spills, you must dispose of it in a landfill. Do not re-incorporate contaminated compost into active or finished compost piles.



Weighted tarps permit compost piles to shed storm water and reduce leachate generation.

Photo: Nick Andrews

Table 6. Relative water quality risk of contrasting feedstock

Feedstock	Nutrient content	Pathogen content	Relative risk to water quality ¹
Ground wood or bark	Low	Low	Low
Fallen deciduous leaves	Low	Low	Low
Ground woody yard debris	Low	Low	Low
Ground leafy yard debris	Medium	Low	Medium
Wood shavings with some horse manure	Low	High	Medium
Separated dairy solids	Low	High	Medium
Vegetable packing waste	Medium	Low	Medium
Vegetative food waste	Medium	Low	Medium
Mixed food waste	High	Medium	High
Bedding and manure	Medium	High	High

Feedstock	Nutrient content	Pathogen content	Relative risk to waterquality ¹
Concentrated manure	High	High	High
Livestock mortalities and slaughterhouse waste	High	High	High

¹Based on authors' professional experience and judgment.

Woody mulch and leaf mulch

Some farmers use woody materials and leaves as mulch for caneberries, rhubarb, fruit trees, or other perennial crops. These mulches are not sources of human pathogens and need not be composted to meet PFRP.

Piling woody materials is usually called aging rather than composting, because it is not a managed process, and the end product does not have the properties of compost. Aged mulch typically is not well mixed, sometimes making it difficult to spread. Plant diseases carried by woody feedstock, such as *Phytophthora ramorum*, are not reliably eliminated by the aging process. For this reason, be cautious in choosing mulch feedstock and in selecting crops for mulch application. Consider composting instead of aging when there is significant risk of plant disease or weed seed spread.

Because woody materials and deciduous tree leaves have a high C:N (carbon to nitrogen ratio), they present a low risk to water quality when stored outdoors without cover. They should be stockpiled at farm locations that are not subject to flooding.

Chapter 6: Manage runoff and leachate

The best way to manage leachate is to prevent its production in the first place. Previous chapters discuss ways to minimize leachate production. This chapter introduces some strategies to manage any leachate that is produced.

Runoff and leachate

Runoff is water that flows off-site. If runoff comes into contact with compost, it becomes leachate and must be managed.

Leachate is contaminated water that has been in direct contact with feedstock or composting materials. This water may be from the composting process itself, or precipitation. Most leachate comes from the alleyways between compost piles. If uncontrolled, leachate can contaminate surface or groundwater and affect human health. Regulators take leachate very seriously, as do managers of sustainable compost operations.

Biological oxygen demand is a measure of the amount of oxygen that is consumed (demanded) by aerobic bacteria as they decompose organic matter in water. As material with high BOD decomposes, dissolved oxygen is depleted; this can be harmful to fish and other aquatic life.

Leachate may contain nitrate, pathogens, metals, salts, other nutrients, and organic compounds with high biological oxygen demand. The threat leachate poses to water quality varies depending on the type of feedstock and the stage of the composting process at which leachate is created. Ammonium-N is more prevalent in the early stages of composting. Nitrate-N is more prevalent as compost reaches maturity.

Compost in earlier processing stages produces higher biological oxygen demand in leachate than more mature compost. The BOD of leachate from food and yard waste compost can range from 2 to 500 mg/L or more. The BOD of clean rivers is less than 1 mg/L. The BOD of moderately polluted rivers may be 2 to 8 mg/L. You can see the potential for serious environmental impacts to water from uncontrolled leachate.

The best use of collected leachate is to moisten an actively composting pile early enough in the process to meet PFRP. Alternatively, collected leachate can be applied to cropland requiring water and nutrients. Determine application rates according to the nutrient content of the leachate and the nutrient requirements of the crop.

Landscape features to protect water quality

Several methods can prevent leachate from reaching surface and groundwater. The key is to ask yourself in advance where runoff or leachate from your site would go. Site slope, soil type, and the type of vegetation in buffer areas dictate the distance needed to separate the composting site from surface water and aquifers.

Filter berms are mesh bags filled with mature compost, woodchips, woody overs, or other coarse material. They filter out large sediment or slow sediment-laden water and allow particulates to settle out. You can place filter berms almost anywhere, and they are particularly useful downslope of the composting site.

Berms are raised banks, usually of soil and compost with grass or other plant cover. Berms provide a second line of defense against leachate migration. Packed soil or fine compost berms can direct water downslope along a desirable path. Berms restrict flow and cause leachate to pool, providing time for it to infiltrate and for sediment to settle out.

A **swale** is a shallow channel that captures and slows runoff and leachate, allowing them to infiltrate. Swales can be planted to grasses or other water-tolerant plants that take up excess nutrients. Sometimes, rock check dams are placed across a swale to slow runoff, increase ponding and increase infiltration.

A **filter strip** is an area of thick vegetation, typically grass, at least 50 feet wide and perpendicular to the direction of runoff flow. Steeper grades require wider filter strips. The vegetation in the filter strip protects underlying soil from erosion, permits leachate to infiltrate, and takes up nutrients.



Saturated compost piles generate leachate, a threat to water quality.

Photo: Nick Andrews

Contaminated water spreads evenly over a well-constructed filter strip or swale, further slowing the water and promoting settling of contaminants. If leachate reaches the end of an effective filter strip or swale, it carries less sediment, nutrients, metals, and pathogens, though it will not be free of these contaminants.

Filter strips and swales are most effective after a filter berm has removed gross sediments. Place filter strips and swales downslope of composting operations and filter berms. They are best as permanent installations at the low points on the property, and should be located some distance from surface water.

These features must be properly designed and built to be effective. Seek professional guidance if needed.

Keep these guidelines in mind for managing leachate

- Prevent stormwater and runoff from coming into contact with compost that is likely to generate leachate.
- Grade the site and use diversion ditches or berms to reduce water flowing through the composting area.
- Use filter berms, berms, filter strips, or swales to keep leachate out of surface water.

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Resources

Oregon Department of Agriculture Natural Resources Division: 503-986-4700 Oregon Department of Environmental Quality (DEQ)

These regional offices can connect you to a hydro-geologist:

- EasternRegion: Bend, 541-633-2025 Providing services to Baker, Crook, Deschutes, Gilliam, Grant, Harney, Hood River, Jefferson, Klamath, Lake, Malheur, Morrow, Sherman, Umatilla, Union, Wallowa, Wasco, and Wheeler

counties

- Northwest Region: Portland, 503-229-5562 Providing services to Clackamas, Clatsop, Columbia, Multnomah, Tillamook, and Washington counties
- Western Region: Eugene, 541-687-7342 Providing services to Benton, Coos, Curry, Douglas, Jackson, Josephine, Lane, Lincoln, Linn, Marion, Polk, and Yamhill counties

[Composting Facility Risk Screening Checklist \(https://www.oregon.gov/deq/mm/swpermits/pages/composting.aspx\)](https://www.oregon.gov/deq/mm/swpermits/pages/composting.aspx), Oregon Department of Environmental Quality.

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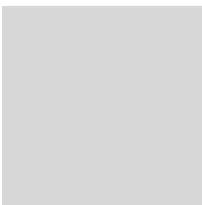
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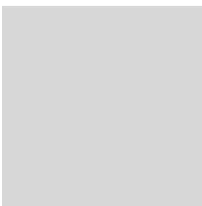
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