Moisture Management: The Key to Successful Composting

by Steven Wisbaum. Revised September 2021

Water is essential to all life on earth, and since the compost process depends on the activity of microbes, it's critically important that compost piles contain ENOUGH moisture. And for the reasons explained below, it's also critical that compost piles don't contain TOO MUCH moisture. Unfortunately, many new compost operators aren't aware of the importance of ensuring optimal moisture throughout the entire composting process, what the moisture content should be, and/or the various methods for ensuring this optimal moisture content. Some of the reasons for this lack of information include:

1. Many composting instruction manuals and "how to" articles place excessive emphasis on achieving an ideal carbon-to-nitrogen ratio, on frequent turning, and achieving high temperatures, rather than on the more important goal of achieving and maintaining optimum moisture throughout the entire compost process.

2. When these instruction manuals and "how to" articles provide a quantitative value for the optimal amount of moisture in a compost pile, these values are often in the range of 40 to 60%, despite the fact that 60% moisture is just barely enough moisture to support microbial activity during the "active" or "hot" compost stage, with levels below 50 or 55% being completely inadequate.

3. Composting is a highly dynamic process with moisture constantly being lost through evaporation and gained through rainfall, and different moisture levels are required at different stages of the compost process. However, many instruction manuals and "how to" articles not only fail to adequately address these moisture dynamics, but also fail to differentiate between the optimal moisture content during the ACTIVE ("hot") composting phase, versus the optimal moisture content during the cooler CURING, and FINISHED composting phases. Specifically, while higher moisture levels are required during the "active" phase when water is being lost through evaporation and turning, less moisture is required at the "curing" or "finished" stages.

4. Sometimes authors of instruction manuals or articles simply don't have much (or any) of their own composting experience and are therefore just relying on information that they've read somewhere, possibly written by someone else with little to no actual composting experience.

So, the first step to understand the optimum amount of moisture required during the various stages of the compost process is to know how to actually calculate "moisture content":

Moisture content is calculated by weighing a sample of compost, completely drying the sample, and then reweighing the dried sample. The moisture content of the original sample is expressed as a percentage and is calculated by dividing the weight of the water that was lost through drying by the weight of the original sample. For example, if the original sample weighs 1 lb and then weighs .5 lb after it's been dried, the weight of the water that was lost is .5 lb, and the moisture content of the original sample would be 50%, or .5 lb divided by 1 lb = .50 (or 50 %).

The Problem of Too Much Moisture

Compost microbes need moisture to survive, but since they're primarily aerobes, they also need adequate supplies of oxygen. In a compost pile, this oxygen is primarily supplied "passively" via "diffusion" and "convection". Diffusion is the process wherein higher concentrations of oxygen in the atmosphere slowly "diffuses" into the interior of the pile where there's a lower concentration. Enhancing this process of diffusion, heat generated inside an active pile rises (via "convection") which pulls in cooler outside air from the bottom and sides of a pile. In "aerated" composting systems, oxygen is supplied using either positive or negative pressure via a system of fans and pipes.

However, with both passive and forced aeration, the supply of oxygen is limited by how easily it can move through the pile, which depends both on the width of the pile, and the amount of "pore space" within the pile, which is largely determined by particle size, shape, and how densely packed the materials are, a measurement known as "bulk density". But another critically important factor that determines how easily oxygen can be replenished is the moisture content, because as the amount of moisture in a pile increases, available pore space is filled with water, thereby displacing and restricting the flow of oxygen. And when a pile becomes saturated with water, aerobic microbes are replaced by anaerobic microbes, resulting in the production of unpleasant odors, and phytotoxic substances. Wet compost is also heavier and denser, making it more difficult and expensive to turn, screen, and transport.

And while there's a common misconception that the primary purpose of "turning" a pile (either with a "compost turner" or a bucket loader) is to "add" oxygen, in-fact, the oxygen that's added during turning is actually used up very quickly. Instead, the main benefits of turning include: mixing and homogenizing ingredients from different zones of the pile; redistributing moisture; breaking apart clumps, and; restoring pile "porosity" that's lost over time due to the reduction in particle size and settling. Additionally, if a pile contains too much moisture, turning can actually compact the ingredients into wet, sticky “clumps”, which even further limits oxygen availability. It’s also worth noting that very high-quality compost can in-fact be made with minimal or no turning, assuming a pile starts out with an optimal amount of moisture and porosity. This idea is described in more detail in another article by Steven Wisbaum titled “Low-Input Composting”.

The Causes of Excess Moisture

Excess moisture in a pile can be caused by either using a mix of raw ingredients that are too wet to begin with, and/or allowing a pile to be exposed to more rainfall than is being lost through evaporation. Different piles at different process stages, at different temperatures, with different types of raw materials having different bulk densities, will all respond differently to increasing moisture levels, but a pile having a moisture content beyond 75% is likely approaching “saturated” conditions. Characteristics of a saturated pile include water seeping out of the bottom as “leachate”, the ingredients becoming wet and slimy, and unpleasant odors that are the by-products of anaerobic decomposition.

Some Ways to Avoid Excess Moisture

Start out with Optimum Moisture Levels

One of the easiest ways to avoid excessive moisture is to start off with a proper mix of dry and wet ingredients to achieve a moisture content of 65 to 70%, which is the amount of moisture that’s contained in a moderately damp, but not “sopping wet” sponge. At this moisture content, you’ll be able to easily squeeze out multiple drops from a sample taken from inside the pile, but you should see little to no leachate flowing out from the bottom of the pile.

Modify Pile Size and Shape

If there’s an elevated risk that a compost pile will be exposed periods of intense and/or prolonged rainfall, and pile size is not limited by the width of a compost turner, the potential for excess moisture conditions can be reduced by building wider and taller piles (versus narrower and shorter piles), which will minimize the amount of surface area for a given amount of material, also known as the “surface-to-volume ratio”. If possible, building a pile with a peaked top will also shed water better compared to a pile with a broad flat top.

Protect Piles with "Compost Covers"

Excess moisture can also be avoided by protecting compost piles with a specialized compost covers such as ComposTex, which is a non-woven, polypropylene, UV-protected, macro-porous fabric that sheds rainfall but is permeable to oxygen. And although it may sometimes be necessary to protect active piles from excess rainfall, compost covers are most commonly used to protect curing or finished compost because compost at this stage is much cooler, has greater water-holding capacity, has minimal evaporative losses, and is more susceptible to becoming too wet. Conversely, as described above, active piles are more likely to need to be exposed to as much rainfall as possible to make up for evaporative losses.

Methods for Reducing the Moisture Content in a Compost Pile That's Too Wet

Add Dry Ingredients

If a pile contains too much moisture and is in the early stages of decomposition (ie. it still contains a relatively large amount of raw or semi-composted ingredients), adding more dry ingredients with a high carbon content and low bulk density will absorb the excess moisture and reduce the pile's bulk density. Examples of the materials that could be added include horse manure with lots of bedding, chopped straw or hay, dry leaves, wood shavings/sawdust, etc.

Protect Piles with Compost Covers

As described above, a wet pile can also be protected from additional rainfall by covering it with a specialized compost covers, such as ComposTex.

If Possible, Use Turning to Accelerate Evaporation

A wet pile can sometimes also be dried out by allowing its surface to dry out, then turning it to mix the outer dry materials with the wetter materials inside the pile, followed by another period of drying, followed by another turn, etc. And if heavy rains are expected during this process, the pile should be covered to prevent exposure to additional water. However, with some materials such as food waste and animal manure, turning can compact materials into wet, dense clumps that will resist decomposition and become hard to break up as they dry out.

Modify Pile Size and Shape

If possible, in hot dry weather, evaporation can be accelerated by reforming a pile into a longer, narrower pile to maximize the surface area that's exposed to the evaporative forces of sun and wind.

The Problem of Not Enough Moisture

While most experienced composters know that compost microbes need moisture to survive, it's my experience that many compost operations operate with sub-optimal moisture levels. One reason for this is that many compost instruction manuals and articles say that a moisture content as low as 40 or 50% is sufficient for composting. And intuitively, it would seem that a moisture content of 50% IS sufficient, since that means that HALF the weight of a pile is water. But considering the fact that compost microbes primarily inhabit the thin moisture layer on the surface of the organic materials they're consuming, that piles with a low-moisture content tend to be hotter and lose water at a faster rate than a wetter pile, and that ingredients taken from inside an active compost pile containing 50% moisture look and feel dry, it's obvious that a 50% moisture content is NOT sufficient for creating an optimal environment for compost microbes.

Unfortunately, many compost manuals and articles also fail to adequately communicate the fact that because composting is a highly dynamic process, more moisture is required at the beginning stages of that process compared to the end of the process, and that there are many factors that have an impact on the moisture content, including:

1. Changes in the concentration and types of microbial activity, the amount of heat generated by those microbes, and the amount of evaporation caused by that heat.

2. The amount of evaporation caused by turning, or by forced aeration.

3. The amount of evaporation caused by exposure of the pile to sun, wind, humidity and outside air temperature.

4. The frequency and volume of rainfall and/or snow-melt, and the effect of pile shape on the amount of water that can penetrate into the pile.

5. The width and height of a pile which determines the amount of surface area for a given volume of material, known as the "surface-to-volume ratio". For example, A HIGHER surface-to-volume ratio will be produced by a given volume of material being formed into a long, narrow pile, versus that same volume of material being formed into a short, wide pile, resulting in a LOWER surface-to-volume ratio.

6. Dry, woody, carbonaceous material tends to be HYDROPHOBIC (ie. it resists wetting), and loses this hydrophobic quality as it decomposes. Therefore, the earlier a sufficiently moist environment is created, the earlier the decomposition process can be initiated, and the sooner these materials will be able to absorb the water needed for decomposition.

7. As woody, carbonaceous materials decompose, their ability to RETAIN moisture also increases, which means that the faster they decompose, the more moisture will be retained in a pile, and therefore the less water will be needed to replace the water lost through evaporation.

8. Because low moisture levels are associated with low bulk density, and low bulk density is associated with increased porosity (ie. air flow), a less-than-optimum moisture content in the active phase of the composting process will create an undesirable feedback loop in which higher temperatures lead to increased evaporation rates, leading to even higher temperatures, leading to even greater evaporation rates, etc.

Indications of Insufficient Moisture

The characteristics of insufficient moisture in a compost pile include: excessively hot pile temperatures (e.g. over 155 degrees F) for extended periods of time; ingredients inside the pile feel dry and are light brown or yellow; few if any water drops can bet squeezed out of a sample taken from inside the pile, and; the ingredients easily fall apart after being squeezed together.

Some Methods to Ensure Sufficient Moisture Throughout the Composting Process

Start out with Optimum Moisture

One of the best ways to ensure that there's sufficient moisture throughout the compost process is to begin with a moisture content of between 65 to 70%. As described above, the presence of optimum moisture will rapidly engage the decomposition process so that pile ingredients start decomposing as quickly as possible, thereby improving their ability to absorb and retain moisture, reduce the rate of moisture loss, reduce process time, and contribute to creating a high-quality finished compost. Starting the compost process with optimal moisture levels can also reduce the need for water to be added manually during the compost process.

Reduce Turning Frequency

As evidenced by billowing clouds of steam released during turning, moisture is lost when the hot moist air from the interior of the pile is exposed to the cooler and drier outside air. Turning also creates additional moisture loss as the moist ingredients that were previously inside the pile are brought to the surface where they're now exposed to the evaporative effects of sun and wind. Therefore, along with the other advantages of reduced turning frequency that are described in the article "Low-Input Composting", reducing turning frequency is one the best ways to minimize moisture loss.

Regularly Check the Interior of the Piles

Piles should be checked regularly to monitor changes in temperature, color, aroma, moisture content, the size and integrity of individual particles, and the ability of a sample to stick together after being squeezed.

Modify Pile Width and Shape to Reduce Moisture Losses and Increase the Moisture Content of Feedstocks and Active Piles from Rainfall and Snowmelt

If a compost site is located in a region that experiences long periods of hot, dry weather, and pile width is not limited by the size of a compost turner, evaporative losses can be minimized by building shorter and wider piles (versus narrower, and longer piles) to minimize the amount of exposed surface area. Whenever possible, feedstocks should also be stored in piles with broad flat tops to absorb as much rainfall as possible.

Protect Piles with "Shade Cloth"

While there are some compost operations in very dry climates that use compost covers to protect piles from the drying effects of sun and wind, despite the fact that ComposTex compost covers are treated to be resistant to UV-light degradation, the lifespan of this fabric will still be reduced when used in this way. Therefore, if there's a need to reduce evaporation, instead of using ComposTex for that purpose, it's more cost effective to use shade cloth (90 to 95% shade), which is designed for extended periods of high UV-light exposure.

If Necessary, Add Moisture to Stockpiled Feedstocks and/or Active Compost Piles

If either stockpiled feedstocks or active compost piles become too dry and there's insufficient rainfall to increase the moisture content, then moisture should be added manually. There are a variety of ways to add moisture, including:

1. **Adding water while turning:** For windrows that are turned, water can be added by using a "watering manifold" installed on a turner.

2. **Drip irrigation:** On either static-aerated piles, or when a turner isn't equipped with a watering manifold, water can be added using multiple drip irrigation lines running along the top of a pile with emitters spaced close enough to wet the entire horizontal cross-section of a pile. However, to ensure that the water doesn't just run down narrow vertical channels and then out the

bottom as “leachate”, the ingredients have to consist of relatively small particles, be semi-digested, and/or not so dry that they’re “hydrophobic” (ie. resist water).

3. **Sprinklers:** In climates or conditions that are not excessively hot, dry, and/or windy, sprinklers can be used to wet the entire surface of the piles. To minimize the amount of water being sprayed on the compost pad and wasted, a sprinkler can be fabricated from one or more 50 ft section of 1.5 to 2 inch flat fire-hose with holes punched along one side at one to three foot spacings. This hose is then laid along the top of the windrow with the HOLES FACING UP. The goal is to create a spray pattern that wets most of the pile surface and then allows the water to seep uniformly into the material below. A relatively short length of hose is used because, unlike drip irrigation lines, the holes aren’t “pressure compensating”, which means that more water will come out of the beginning of the hose than towards the end of the hose.

But whatever method is used to add water to a pile, the volume of water needed to appreciably increase the moisture content of a dry compost pile is likely to be much higher than most people would imagine. For example:

- Assume “Pile A” contains 300 cu yd of material, and weighs 180,000 lbs (@ 600 lb/cu yd).
- If this pile has a moisture content of 50%, that means it contains 90,000 lbs of water.
- Therefore, increasing the moisture content of that pile to 65% will require adding around 75,000 lb of water, or approximately 9,000 gallons (@8.34 lb/gal).

Here's the math:

1. 300 cu yd of material weighs 180,000 lbs (weight of ingredients including H2O)
2. 180,000 lbs x 50% H2O = 90,000 lbs H2O (original H2O weight)
3. 90,000 lbs H2O + 75,000 lbs (additional) H2O = 165,000 lbs H2O (new total H2O weight)
4. 90,000 lbs (original weight of dry ingredients) + 165,000 lbs H2O = 255,000 lbs (weight of ingredients, original amount of water, and additional water)
5. 165,000 lbs H2O divided by 255,000 lbs = 65% H2O

The Connection Between Insufficient Moisture, Excessive Temperatures, and Turning

Many compost instruction manuals and articles describe temperatures in the range of 150 to 155 degrees F for active compost piles as both desirable and normal. And while there are many disadvantages of such high temperatures as described in the article "Low-Input Composting", I suspect that the main reason that these high temperatures are considered normal and desirable, is that the problem of compost piles not having enough is so common.

In-fact, due to the cooling effect of moisture, active compost piles that have a moisture content of 65 to 70% will rarely have temperatures above 140 or 145 degrees F. Yet, inexplicably, rather than recommending higher moisture levels to avoid or reduce excessive temperatures, turning is often recommended, despite the fact that after a brief cooling effect, turning will actually INCREASE temperatures by both temporarily spiking oxygen concentrations, and accelerating evaporation rates.

Finally, for those who might worry that adding water to achieve an initial moisture content to 65 to70% would be a waste of water, since piles starting out with optimal moisture levels will gain water-holding properties faster and will have lower temperatures and reduced evaporation rates, these piles will actually lose LESS water compared to piles that start out with sub-optimal moisture levels.

Moisture Levels in Curing or Finished Compost

As the process moves from the active phase to the "curing" and "finished" phase, there's less microbial activity, less heat being generated, and less evaporation. Therefore, assuming the compost has truly entered the "curing" and "finished" phase (ie. it has a dark color, has an "earthy" aroma, and relatively few identifiable particles, a lower moisture content in the range of 45% to 50% is both adequate and desirable since this will reduce the weight of the finished compost, will make it easier and less expensive to screen, bag and/or transport, while still providing sufficient moisture to support some microbial activity. For reference, a moisture content of 45% to 50% would be the amount of moisture in a just slightly "damp" sponge.

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