2012

A Guide to Composting at UMM

University of Minnesota
MORRIS

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Section 1: Facility Siting and Design

1.1 *Facility Siting*

- **Technical, social, economic, political factors shape siting decision**
    - Convenient location to minimize hauling distances
    - Assurance of an adequate buffer between the facility and nearby residents
    - Suitable site topography and soil characteristics
    - Sufficient land area for the volume and type of material to be processed
        - To operate efficiently, a composting facility must allot sufficient space to the preprocessing, processing, and postprocessing compost stages as well as to the surrounding buffer zone[1]
- Site assessment factors
    - Site preparation costs (compost area development)
        - Depending on soil and drainage characteristics, it may be necessary or advantageous to construct a compacted gravel pad or an impermeable asphalt or concrete pad on which to mix the materials and form the windrows[2]
    - Site characteristics
        - Soil characteristics
            - If the site is unpaved, the soil on the site should be permeable enough to ensure that excess water is absorbed during periods of heavy precipitation and that the upper layers of the soil do not become waterlogged (this can create pooling and limit vehicular access)
        - Proximity to water, streams, lakes
        - Slope and topography
            - Site should be properly graded to avoid runoff and standing pools of water
            - **Land slope at a composting site should be at least 1 percent and ideally 2 to 4 percent**
                - Windrows should be arranged parallel to the grade to allow runoff to flow between the piles instead of through them
                - Poor site drainage leads to pending of water, saturated composting materials, muddy and unsightly site conditions, bad odors, and excessive runoff and leachate
        - Acreage
            - Communities should be careful not to locate a facility on too small a site as this can decrease plant efficiency and increase operational costs
            - The land area of a composting facility must be large enough to handle both present and future projected volumes
            - Ideally a composting facility should have, at a minimum, enough acreage to accommodate an entire year's projected volume of incoming feedstock on the site

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[1] http://www.epa.gov/ttnatw01/burn/burnalt1.pdf (page 56-60)
[2] http://www.mass.gov/agr/programs/compost/docs/Guide_to_Ag_Composting2010.pdf (page 11)

- **Operations that use a front-end loader to turn the material require individual rows and aisles between the windrows of 15 to 20 feet**[3]
- consideration must be made for the area required for drop-off and mixing of materials, equipment maneuvering, curing areas, storage of finished compost, and buffer areas between the compost site and sensitive land uses[4]
    - Drainage
  - Access by public roads
  - Infrastructure
    - Water
      - The composting site should have a water source for properly controlling the moisture content of the composting process.
      - The amount and source of the water to be supplied depends on the nature of the compostables, the composting technology used, the size of the operation, and the climate. For example, dry leaves generally require 20 gallons of water per cubic yard of leaves whereas feedstocks with high moisture content (e.g., food scraps) will require less water[5]
      - **Operations may need to have a water supply for wetting the piles if they become too dry, and for fire protection**. Possible sources include ponds, streams, wells, public water supply, or water trucks
        - Water requirements would be largely based on the moisture content of the incoming feedstocks and to a lesser degree on weather conditions during composting[6]
    - Existing access road
    - Storage
  - Proximity to homes
  - Environment impact
    - Tree removal
    - Habitat disturbance
    - Water quality
      - **In general, the water table should be no higher than 24 inches below the soil surface**. Otherwise, flooding can occur during times of heavy precipitation, which can potentially wash away windrows and carry compostable materials off site.
      - leachate from composting operations is more likely to contaminate ground water when there is less soil to naturally falter the leachate as it seeps downward
  - Impact on current use
    - Visual
    - Physical
  - Land ownership
- Ways to address potential impacts

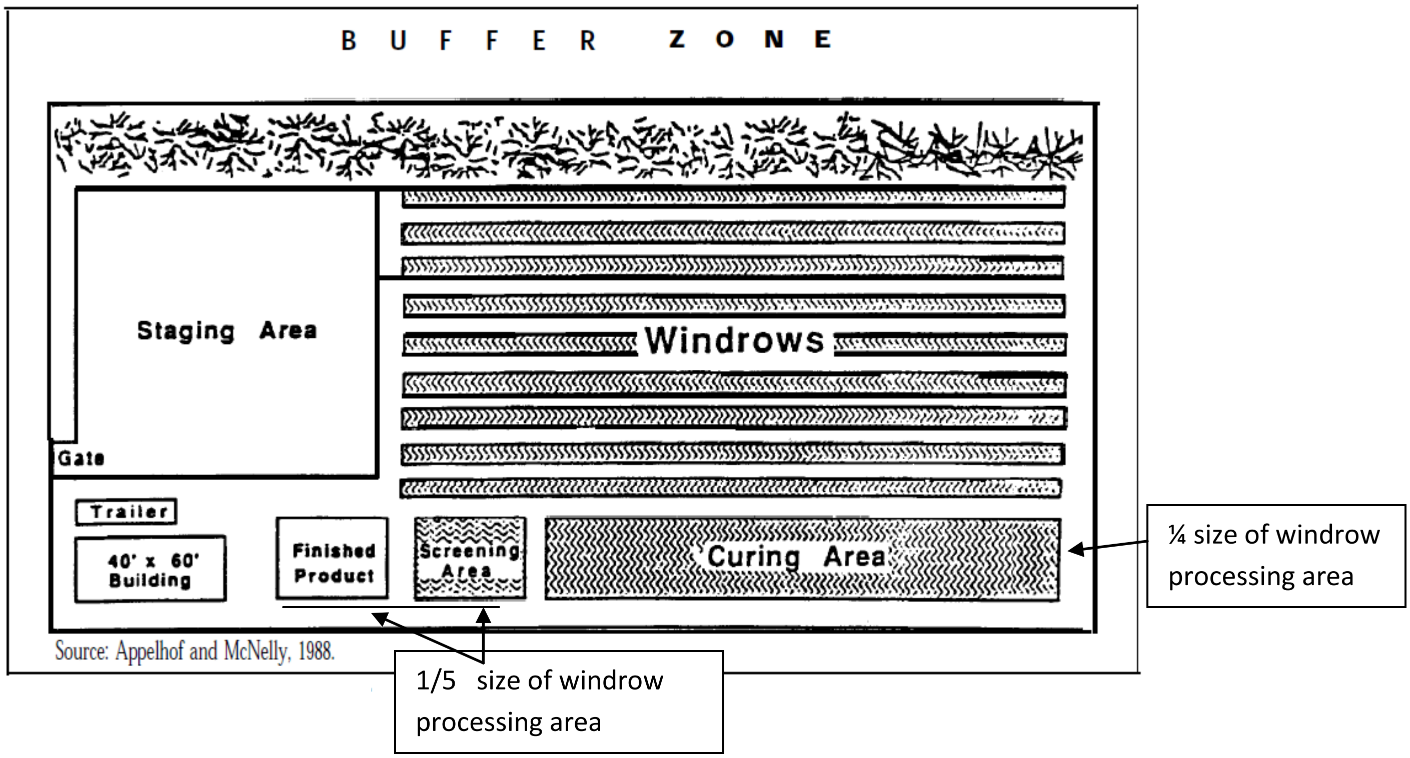
[3] http://www.epa.gov/ttnatw01/burn/burnalt1.pdf (page 56-60)
[4] http://www.mass.gov/agr/programs/compost/docs/Guide_to_Ag_Composting2010.pdf (page 10)
[5] http://www.epa.gov/ttnatw01/burn/burnalt1.pdf (page 56-60)
[6] http://www.mass.gov/agr/programs/compost/docs/Guide_to_Ag_Composting2010.pdf (page 12)

- locate site with extensive natural buffer zone planted with trees and shrubs[7]

1.2 *Facility Design*

- Critical aspects of design:
    - <u>preprocessing area</u>
        - **A preprocessing or staging area offers room to receive collected feedstock and sort or separate materials as needed.**
        - Receiving materials in a preprocessing area will eliminate the need for delivery trucks to unload directly into windrows in poor weather conditions.
        - The size and design of the preprocessing area depends on the amount of incoming materials and the way the materials are collected and sorted
        - The tipping area floor should be strong enough to support collection vehicles and hardened to withstand the scraping of equipment such as front-end loaders.
            - The tipping floor also should contain no pits, which can attract vermin.
            - Concrete floor slabs and pushwalls to run the front-end loaders against when scooping MSW will increase the efficiency of the operation.
    - <u>processing area</u>
        - **composting area and curing area**
        - the curing area needs less space, requiring only about one quarter of the area of the compost pad
    - <u>post processing area</u>
        - **can be used to conduct quality control testing of compost to perform screening, size reduction, and blending operations; to compost in preparation for market; and to store the compost**
            - A space about one- fifth the area of the composting pad is sufficient
        - If the finished compost will not be delivered to the end user within a relatively short period of time, the compost should be covered. Otherwise, winds can transport weed seeds into the piles, which can support the growth of unwanted plants and devalue the product
        - Cured compost should be stored away from surface water and drainage paths
    - <u>Buffer zone</u>
        - The buffer zone frequently needs to be several times the size of the composting pad, particularly when the composting operation is adjacent to residential areas or businesses
        - During site design, the direction of the prevailing wind (if one exists) should be noted and the buffer zone extended in this direction. This will help minimize the transport of odor and bioaerosols downwind of the facility

[7] http://www.epa.gov/ttnatw01/burn/burnalt1.pdf (page 56-60)



Source: Appelhof and McNelly, 1988.

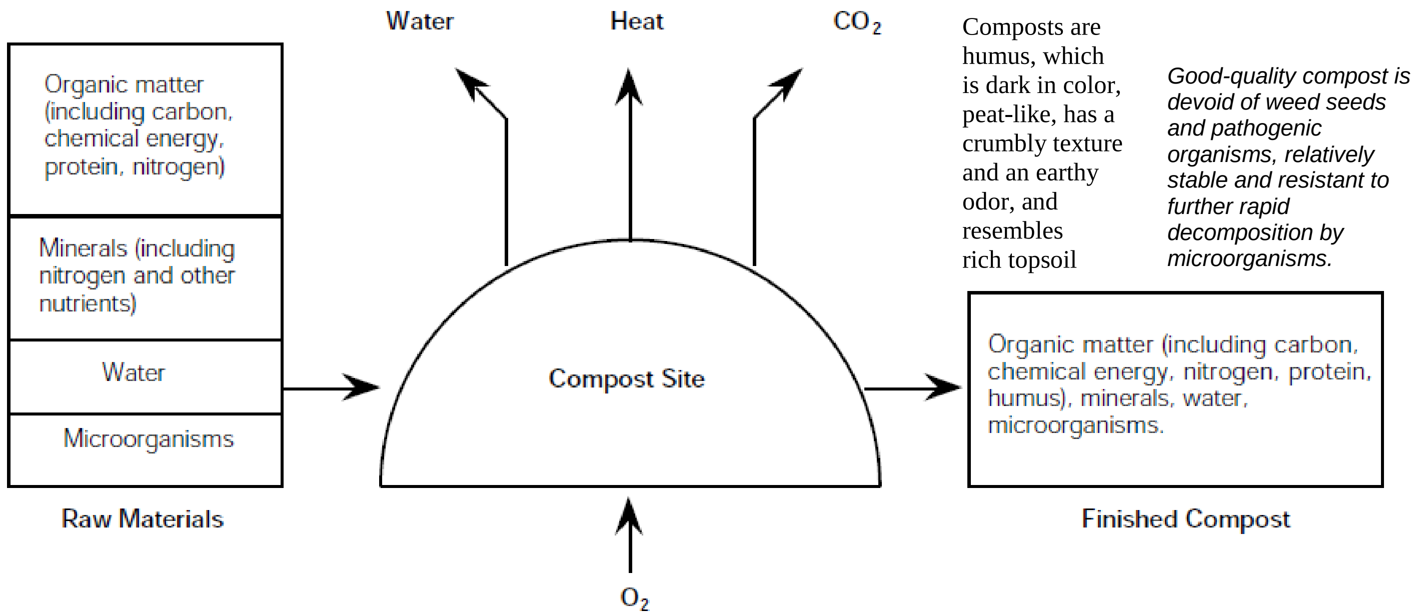
- Surface for operations
    - We have clay soil so that is enough to protect the environment but we may want more than just the soil as a working surface for ease of management
        - **We may want to bring gravel in later on for management purposes** since the site may get sloppy in the spring
        - Active composting area would have compacted gravel but dirt would be just fine for the curing area
    - **Costs for surface operations are minimized when there is a bunkered tipping and mixing option**
    - The most important considerations is to make sure that there is access to all parts of the process in order to avoid odor issues and incomplete management
        - There must be access to the bunker, windrows, curing, and screening areas
    - If possible, the site should be slope a little bit to avoid water accumulating[8]

Section 2: Regulation of Natural Processes

[8] Black, Ginny. "MPCA Organics Specialist." Email. 17 Feb. 2012.

Figure 7-1

The Composting Process



The carbon, chemical energy, protein, and water in the finished compost is less than that in the raw materials. The finished compost has more humus. The volume of the finished compost is 50% or less of the volume of raw material.

Source: Reprinted with permission from Rynk, et al., *On Farm Composting Handbook, 1992 (NRAES-54)*

[9]

Proper Conditions for Organic Composting

- An adequate supply of oxygen for microbial respiration (approximately 5 percent of the pore space in the starting material should contain air).
- A moisture content between 40 and 65 percent.
- Particle sizes of composting materials of approximately 1/8-inch to 2 inches in diameter.
- A carbon to nitrogen (C:N) ratio between 25:1 and 40:1. Later on in this publication, we'll more fully discuss the critical importance of the C:N ratio.

[10]

[9] http://www.epa.gov/osw/nonhaz/municipal/dmg2/chapter7.pdf (page7-8)

2.1 *Oxygen Control*

- **Favorable composting microbes need air to survive**
    - If the pile becomes too compacted or too wet, air won't reach all the microbes
    - If the pile contains too many nitrogen-rich materials, oxygen will be too quickly consumed by the microbes and deplete the pile.
        - Anaerobic microbes will take over, and odors will occur.
        - Alcohols may also form, which are toxic to growing plants.
- **To avoid anaerobic decomposition, turn the pile as needed or incorporate stiff bulking agents to increase porosity throughout the pile**[11]
- Microorganisms important to the composting process require oxygen to break down the organic compounds in the composting feedstock
- To support aerobic microbial activity, void spaces must be present in the composting material.
    - These voids need to be filled with air
    - Oxygen can be provided by mixing or turning the pile
- Required oxygen amounts dependent on:
    1. Stage of the process: oxygen needs to be supplied in initial stages, not during curing
    2. Type of feedstock: Dense, nitrogen-rich materials (e.g., grass clippings) will require more oxygen
    3. The particle size of the feedstock - Feedstock materials of small particle size (e.g., less than 1 or 2 inches in diameter) will compact, reducing void spaces and inhibiting the movement of oxygen
    4. The moisture content of the feedstock - Materials with high moisture content (e.g., food scraps, garden trimmings) will require more oxygen[12]

2.2 *Temperature Control*

- **Ideal temperature is between 131-160ºF (55-70ºC), and should be determined by inserting a composting thermometer horizontally into the center of the pile**
    - Temperature is an indication that the organisms are working well, releasing energy as they break apart organic compounds
    - Maintaining temperatures within this range is important because the composter must ensure that all pathogens are being killed
- If temperature is too low, examine the pile for particle size, air circulation and moisture, and review the pile recipe to determine why the pile temperature is low
    - If temperatures exceed the ideal range, aerate the pile, and add moisture if needed[13]
- Microorganisms tend to decompose materials most efficiently at the higher ends of their tolerated temperature ranges
    - The rate of microbial decomposition therefore increases as temperatures rise until an absolute upper limit is reached.

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[10] http://www.cefs.ncsu.edu/resources/organicproductionguide/compostingfinaljan2009.pdf (page 2)
[11] http://compostingcouncil.org/admin/wp-content/uploads/2010/09/BMP-for-FW-to-YW.pdf
[12] http://www.epa.gov/ttnatw01/burn/burnalt1.pdf (page 18)
[13] http://compostingcouncil.org/admin/wp-content/uploads/2010/09/BMP-for-FW-to-YW.pdf

- As a result, the most effective compost managing plan is to maintain temperatures at the highest level possible without inhibiting the rate of microbial decomposition[14]

- **Both the mesophilic range (90-110°F) and the thermophilic range (120° to 150°F) supports microorganisms that decompose organic materials**
  - The most active phase of composting happens mainly in the thermophilic range
    - It is also in this range that pathogens and weed seeds are destroyed
  - If the proper conditions exist, the pile begins to heat up almost right away
    - This **first phase of composting, lasting one to two days, is called the *mesophilic stage***. In this stage, strains of microorganisms (the species that are most active at temperatures of 90° to 110°F) begin to break down the readily degradable compounds in the pile
    - The **next phase in the composting process is the *thermophilic stage*, which can last for several weeks**. At these temperatures, heat-loving (thermophilic) bacteria vigorously degrade the organic material
      - Temperatures will remain in this range as long as decomposable materials are available and oxygen is adequate for microbial activity
      - Pathogens are destroyed as the heat in the pile climbs above a critical temperature of 131°F. **Fly larvae and most weed seeds are destroyed at temperatures above 145°F**[15]
- As temperature exceeds 140°F, the rate of decomposition begins to decline as a less-efficient class of thermophilic organisms dominates
  - recommended to maintain temperatures between 100-140°F for efficient composting during the active phase.
  - When temperatures move out of the optimum range, it is usually because the level of oxygen has dropped too low or moisture level is no longer optimal (either too dry or too wet)
- Monitoring the temperatures in a composting pile provides a good guide as to when remedial measures may be needed to maintain or return to efficient composting conditions. Turning the compost piles greatly helps in moderating temperatures [16]

2.3 *Moisture Control*

- **Ideal moisture content is around 50%, meaning that if you pick-up a handful of compost (taken from a couple of inches inside the pile) and squeeze it, a drop of moisture should fall from your hand. *Barely* a drop.**
- If the pile is too dry, the microbes go dormant. If the pile is too wet, the pile can go anaerobic due to lack of oxygen circulation. Add water or dry materials as needed, and stir the pile to mix moisture throughout[17]

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[14] http://www.epa.gov/ttnatw01/burn/burnalt1.pdf (page 19)
[15] http://www.cefs.ncsu.edu/resources/organicproductionguide/compostingfinaljan2009.pdf (page 3)
[16] http://www.mass.gov/agr/programs/compost/docs/Guide_to_Ag_Composting2010.pdf (page 6)
[17] http://compostingcouncil.org/admin/wp-content/uploads/2010/09/BMP-for-FW-to-YW.pdf

> **The Moisture Squeeze Test**
> A general rule of thumb is that the pile is too wet if water can be squeezed out
> of a handful of compost and too dry if the handful does not feel moist to the touch.

[18]

- Moisture content in the feedstock varies widely.
  - With yard trimmings, the moisture content of leaves tends to be lower than optimal.
    - Moisture, therefore, should be added to dry leaves, generally at a level of about 20 gallons of water per cubic yard of leaves
    - During the early stages of composting leaves must be mixed during wetting to prevent the water from running off the pile surface.
  - The moisture content of grass tends to be higher than optimal
    - Grass should be mixed with drier materials (such as leaves or wood chips) or turned more frequently during the initial stages of processing to facilitate the evaporation of excess water[19]
- Evaporation from compost piles can be minimized by controlling the size of piles: piles with larger volumes have less evaporating surface/unit volume than smaller piles
- **The water added must be thoroughly mixed so all portions of the organic fraction in the bulk of the material are uniformly wetted and composted under ideal conditions**
  - Properly wetted compost has the consistency of a wet sponge[20]

2.4 *Particle Size*

- **The optimum particle size has enough surface area for rapid microbial activity, but also enough void space to allow air to circulate for microbial respiration**
  - The feedstock composition can be manipulated to create the desired mix of particle size and void space[21]
- The smaller the materials, the faster the organisms can break them down. Grinding materials is not necessary, but may speed the process if needed[22]
- In general, the smaller the shreds of composting feedstock, the higher the composting rate.
  - Smaller feedstock materials have greater surface areas in comparison to their volumes.
    - This means that more of the particle surface is exposed to direct microbial action and decomposition in the initial stages of composting[23]
- Materials with very small particle size, such as sawdust, can become anaerobic due to compaction and restricted oxygen flow[24]

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[18] http://www.cefs.ncsu.edu/resources/organicproductionguide/compostingfinaljan2009.pdf (page 4)
[19] http://www.epa.gov/ttnatw01/burn/burnalt1.pdf (page 38)
[20] http://www.epa.gov/osw/nonhaz/municipal/dmg2/chapter7.pdf (page 7-13)
[21] http://www.epa.gov/osw/nonhaz/municipal/dmg2/chapter7.pdf (page 7-14)
[22] http://compostingcouncil.org/admin/wp-content/uploads/2010/09/BMP-for-FW-to-YW.pdf
[23] http://www.epa.gov/ttnatw01/burn/burnalt1.pdf (page 18)
[24] http://www.mass.gov/agr/programs/compost/docs/Guide_to_Ag_Composting2010.pdf (page 6)

2.5 *Odor Problem-Solving*

- If materials are mixed so that the C:N ratio is within acceptable range, moisture content is between 45-60%, and materials are not compacted and have proper aeration (via whichever method is chosen), odors should not be an ongoing problem

- Odors *are* present when initially receiving and mixing piles, after turning piles (if applicable), and in response to changing conditions, however, and the composter should be prepared to remedy the situation as quickly as possible
- The first step is to determine the reason for odors. Too much nitrogen relative to carbon? Too much moisture? Not enough air circulating?
- *Odors may emerge, but they need not be problematic*

- The following illustrates several possibilities for odors, and the respective solutions[25]

Problem	Solution
waste smells upon arrival	know when residuals arrive so that personnel can be available to mix and pile or windrow them immediately
after many days of rain the sun has emerged, piles smell	turn pile daily until favorable moisture content is once again achieved, cover with a 3" layer of finished compost after turning
random odors emerge two weeks after food residuals arrived and were mixed	turn piles, add additional carbon-rich materials if needed

- Preventative measures for odors:
1. Forming incoming materials into windrows promptly
2. Making sure windrows are small enough to ensure that oxygen can penetrate from the outside and guard against the formation of a foul-smelling anaerobic core but large enough for the interior to reach optimal temperatures.
3. Providing aeration by completely mixing the feedstock and regularly turning the piles
4. Because turning can release odors, however, a windsock can be used for determining when conditions are right for turning so as to keep odors from leaving the site.
5. Breaking down piles that are wet and odorous and spreading them for drying. Mixing in dried compost that has been cured also can help.
6. Avoiding standing pools of water or pending through proper grading and use of equipment [26]

2.6 *Carbon to Nitrogen Ratio*

- For rapid decomposition, the ideal carbon to nitrogen ratio is 30 to 1 (30:1). That ratio represents 30 parts carbon to 1 part nitrogen by weight[27]

[25] http://compostingcouncil.org/admin/wp-content/uploads/2010/09/BMP-for-FW-to-YW.pdf
[26] http://www.epa.gov/ttnatw01/burn/burnalt1.pdf (page 48)
[27] http://www.mass.gov/agr/programs/compost/docs/Guide_to_Ag_Composting2010.pdf (page 5)

- composting proceeds most efficiently when the C:N ratio of the composting material is from 25:1 to 35:1

  - When the C:N ratio is greater than 35:1, the composting process slows down.
  - When the ratio is less than 25:1, there can be odor problems due to anaerobic conditions, release of ammonia, and accelerated decomposition[28]
  - Finished compost should have ratios of 15 to 20:1[29]

- High C:N ratios (i.e., high C and low N levels) inhibit the growth of microorganisms that degrade compost feedstock
- Low C:N ratios (i.e., low C and high N levels) initially accelerate microbial growth and decomposition

  - With this acceleration, however, available oxygen is rapidly depleted and anaerobic, foul-smelling conditions result if the pile is not aerated properly. The excess N is released as ammonia gas.
  - Extreme amounts of N in a composting mass can form enough ammonia to be toxic to the microbial population, further inhibiting the composting process
  - Excess N can also be lost in leachate, in nitrate, ammonia, or organic forms[30]

- Carbon to nitrogen ratio: the "recipe" of ingredients used to compel the microbes to compost quickly and completely

  - Get the mixture right and the microbes work faster.
  - Get it *wrong*, and either the process will slow significantly or the pile will start to smell.

- Carbon serves as the energy source for the microbes, and nitrogen is the protein source for cell building and reproduction. One without the other doesn't work.

  - While scientifically "carbon-to-nitrogen ratio" (C:N ratio), is calculated on an elemental weight basis, **operators can more simply consider the term as a reference to the proportion of high-carbon materials versus the proportion of high-nitrogen materials, on wet weight or bulk volume basis** (such as "three parts leaves to one part grass", or "one ton of sawdust to one ton of food residuals").
  - It isn't sufficient to have the right ingredients in the pile. They must be in the right proportions to ensure the microbes will work quickly and effectively to produce a usable end compost product[31]

2.7 *Role of Microorganisms*

- Composting is a succession of microbial activities whereby the environment created by one group of microorganisms invites the activity of successor groups

  - Different types of microorganisms are therefore active at different times in the composting pile

    - Bacteria have the most significant effect on the decomposition process, and are the first to take hold in the composting pile, processing readily decomposable nutrients (primarily proteins, carbohydrates, and sugars) faster than any other type of microorganism.

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[28] http://www.epa.gov/ttnatw01/burn/burnalt1.pdf (page 39)
[29] http://www.epa.gov/osw/nonhaz/municipal/dmg2/chapter7.pdf (page 7-12)
[30] http://www.epa.gov/ttnatw01/burn/burnalt1.pdf (page 19)
[31] http://compostingcouncil.org/admin/wp-content/uploads/2010/09/BMP-for-FW-to-YW.pdf

- Fungi, which compete with bacteria for food, play an important role later in the process as the pile dries, since fungi can tolerate low-moisture environments better than bacteria
  - Some types of fungi also have lower nitrogen requirements than bacteria and are therefore able to decompose cellulose materials, which bacteria cannot
- Microorganisms also play a role in the composting process.
  - Rotifers, nematodes, mites, springtails, sowbugs, beetles, and earthworms reduce the size of the composting feedstock by foraging, moving in the compost pile, or chewing the composting materials
    - These actions physically break down the materials, creating greater surface area and sites for microbial action to occur.
    - The microorganisms necessary for composting are naturally present in most organic materials, including leaves, grass clippings, and other yard trimmings, and other organic materials

- **Products are available that claim to speed the composting process through the introduction of selected strains of bacteria, but tests have shown that inoculating compost piles in this manner is not necessary for effective composting of typical yard trimmings or MSW**[32]

2.8 *Time needed for composting*

- Composting is an accelerated decomposition process; however, the length of time it takes to go from raw materials to stabilized, finished compost can vary considerably
  - If all the above basic conditions are maintained at optimal levels, then compost times can be as short as a few weeks
  - If, on the other hand, piles are turned infrequently, or the C:N ratio of the mixture is too high, then composting can take a year or more
- There are two main phases to composting
  1) **Active phase**
     - During this phase of rapid decomposition, temperatures in the pile increase to **130–150°F** and may remain elevated for several weeks[33]
     - This is where temperatures fluctuate between the thermophilic and mesophilic ranges and decomposition is rapid
     - A newly formed compost pile will quickly reach high temperatures and then as microbes use up the available oxygen, they will become less active and temperatures will drop
     - Introducing more oxygen into the pile by turning will cause the microbes to multiply rapidly again and the active phase will continue until oxygen is again deplete
     - This cycle will repeat – temperature drop, aeration, temperature rise – until all the easily digestible organic material is consumed by the microbes. When

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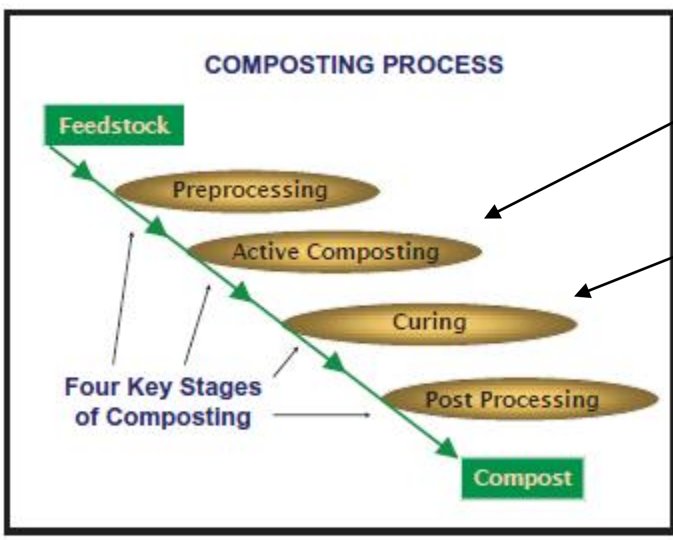
[32] http://www.epa.gov/ttnatw01/burn/burnalt1.pdf (page 16)
[33] http://www.extension.org/pages/18567/making-and-using-compost-for-organic-farming

temperatures do not again rise after turning, then the compost is ready for the "curing" phase[34]

2) **Curing Phase**

- As readily available organic matter is consumed and decomposition slows, temperatures in the compost pile decrease to around **100°F** and the curing phase begins. At this stage, the compost can be stockpiled[35]
- In the curing phase, different populations of microbes continue to decompose but at lower temperatures
- This phase can last one to several months, during which time the compost becomes stabilized in the sense that by-products, such as ammonia, are no longer being generated in amounts that would be harmful to plants if compost were applied to the soil[36]
- The final product should be dark brown to black in color, sweet smelling or at least neutral in aroma, soil-like in texture, and with particles reduced to ½-inch or less in diameter
    - None of the original *feedstocks*, the materials used to make the compost, should be recognizable[37]

Section 3: Operational Steps



[38]

Transition marked by steady decline in temperature

Generally takes between **3 – 8 weeks**

Takes **At least 4 weeks** to obtain quality finished product **but up to 6 months**

Often, curing piles are also compost storage piles

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[34] http://www.mass.gov/agr/programs/compost/docs/Guide_to_Ag_Composting2010.pdf (page 7)
[35] http://www.extension.org/pages/18567/making-and-using-compost-for-organic-farming
[36] http://www.mass.gov/agr/programs/compost/docs/Guide_to_Ag_Composting2010.pdf (page 7)
[37] http://www.cefs.ncsu.edu/resources/organicproductionguide/compostingfinaljan2009.pdf (page 2)
[38] http://www.transformcompostsystems.com/pdfs/Transform%20Compost%20Operator%20Manual%20teaser.pdf (page 4 and 71)

3.1 *Delivery of Compostable Materials*

Receive and mix adjacent to windrow of destination.

3.2 *Mixing*

- **Mixing entails either blending certain ingredients with feedstock materials or combining different types of feedstock materials together**
    - For example, bulking agents (such as wood chips) are often added to feedstock materials that have a fine particle size (such as grass)
    - **Bulking agents have the structural integrity to maintain adequate porosity and help to maintain aerobic conditions in the compost pile**
        - Bulking agents are dry materials and tend to have high carbon content.
            - Therefore whenever bulking agents are used, care should be taken to ensure that C:N ratios do not become too high
    - Mixing is most efficient when it is conducted after feedstock sorting and size reduction and before processing begins
    - For simple composting operations that do not require high levels of precision, mixing can be performed during size reduction or pile formation by feeding different ingredients or types of materials into these operations[39]
- Mix materials according to approximate carbon: nitrogen ratios (30:1 being ideal). **If mixing isn't immediately possible, start by covering the load with a layer of high-carbon materials or finished compost until mixing and incorporating into permanent piles is feasible.**
- It is not recommended to leave food residuals unmixed for more than 24 hours, as liquids will continue leaching until carbon-rich materials are added. Pests (including rats) will likely be attracted[40]
- **Option of having a tipping and mixing area using a 3-sided bunker**
    - bunker with wood chips on bottom so that free liquids are absorbed; mix it up so material is ready to build windrow
    - bunkered: use concrete walls to push material against and mix
    - will have to determine how truck comes into site, can use skid loader to mix browns and food waste
    - think about how truck is coming into site, where bunker would go
        Ex) come from cafeteria, hit bunker (browns all ready to go), dump food waste on browns, mix it up, compostable bags will break up as mixing up[41]

3.3 *Windrow Construction*

- Approximately two static windrow piles will be required. When the first pile is completed, it must "sit there." Add to the second pile while the first pile is maturing. The temperature

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39 http://www.epa.gov/ttnatw01/burn/burnalt1.pdf (page 39)
40 http://compostingcouncil.org/admin/wp-content/uploads/2010/09/BMP-for-FW-to-YW.pdf
41 Black, Ginny. "MPCA Organics Specialist." Personal interview. 13 Feb. 2012.

of the first pile (while building the second pile) must be 131ºF for two weeks in order to comply with the process to further reduce pathogens (PFRP)[42]

- Making the windrow will be done just like how it is done with the yard waste
    - Start heaping up one corner, and then move down (**get to height of 3 – 5 feet first**), and progressively work down
    - Either start another windrow or may be done enough, move to curing area (just a big pile), and let it sit for a couple of months (maybe even 6 months until you want to screen it and use it), start again and rebuild windrow
    - May want to recover wood chips in order to allow for reinoculation, reintroducing the bugs and bacteria[43]
- Windrows are elongated composting piles that are turned frequently to maintain aerobic composting conditions
    - The frequent turning promotes uniform decomposition of composting materials as cooler outer layers of the compost pile are moved to inner layers where they are exposed to higher temperatures and more intensive microbial activity
    - **The turned windrow method results in the completion of the composting process for yard trimmings in approximately 3 months to 1 year**
- Progressive decomposition of the composting materials reduces the size of the windrows, allowing them to be combined to create space for new windrows or other processes
- The ideal height for windrows is from 5 to 6 feet
    - This height allows the composting materials to be insulated properly but prevents the buildup of excessive heat
        - Windrow heights vary, however, based on the feedstock, the season, the region in which the composting operation is being conducted, the tendency of the composting materials to compact, and the turning equipment that is used
- **Windrow widths are generally twice the width the height of the piles**[44]
- With our size of operations, a height of 3 – 5 feet is good[45]
- Windrows with concave crests are appropriate during dry periods and when the moisture content of the composting material is low to allow precipitation to be captured more efficiently
- Peaked windrows are preferable during rainy periods to promote runoff of excess water and to prevent saturation

[42] Black, Ginny. "MPCA Organics Specialist." Personal interview. 21 Dec. 2011.
[43] Black, Ginny. "MPCA Organics Specialist." Personal interview. 13 Feb. 2012.
[44] http://www.epa.gov/ttnatw01/burn/burnalt1.pdf (pages 41-42)
[45] Black, Ginny. "MPCA Organics Specialist." Personal interview. 13 Feb. 2012.

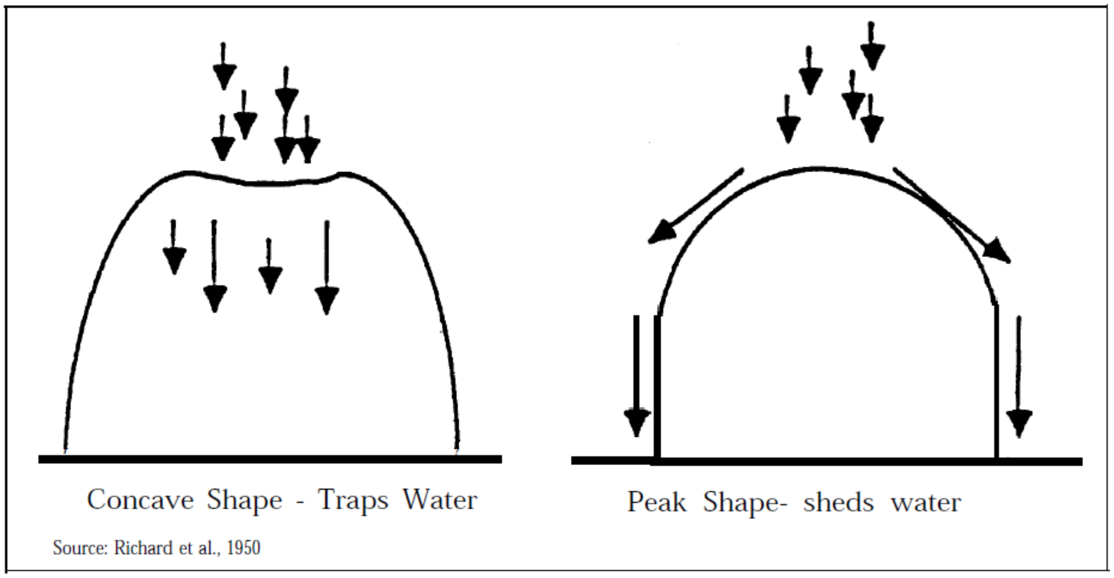

Figure 4-10. Windrow shapes for maximum and minimum water adsorption.
[46]

- As decomposition progresses, the piles will shrink in size from 25% to 75% of the original size depending on the density of the original mix. Two or more windrows may then be combined to make room for new raw materials[47]

3.4 *Pile Turning*

- Pile should be turned 4-5 times within the 21 day period of 131 or more degrees Fahrenheit so that everything is exposed to high temperatures needed to kill pathogens[48]
- Turning windrows ensures materials are evenly mixed and exposed to high temperatures in the pile's core. If odors emerge after turning, windrows can be covered with a 3-6" layer of finished compost[49]
- Windrow composting is a year round activity. If interior pile conditions warrant turning in the winter, the operator should select a day when the temperature is above freezing to turn the piles, if possible[50]
- In general, the more frequently that the piles are turned, the more quickly the composting process is completed
    - Ideal turning patterns should move the outside layers of the original windrow to the interior of the rebuilt windrow
    - If this pattern is not feasible, then care should be taken to ensure that all materials spend sufficient time in the interior of the pile.
        - Inefficiencies in the turning pattern can be compensated for by increasing the frequency with which the windrows are turned[51]

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[46] http://www.epa.gov/ttnatw01/burn/burnalt1.pdf (page 43)
[47]http://www.mass.gov/agr/programs/compost/docs/Guide_to_Ag_Composting2010.pdf (page 8)
[48] Black, Ginny. "MPCA Organics Specialist." Personal interview. 13 Feb. 2012.
[49] http://compostingcouncil.org/admin/wp-content/uploads/2010/09/BMP-for-FW-to-YW.pdf
[50] http://www.mass.gov/agr/programs/compost/docs/Guide_to_Ag_Composting2010.pdf (page 8)

- **Front-end loaders are commonly used in smaller operations**
    - The quantity of materials that they can handle as well as the control that they can exercise over the turning process is limited, however.
    - When this equipment is used, enough space must be maintained between windrows to allow the front-end loaders to maneuver and turn the piles[52]

3.5 *Curing Process*

- The composting process occurs in two major phases
    - In the first stage, microorganisms decompose the composting feedstock into simpler compounds, producing heat as a result of their metabolic activities
        - The size of the composting pile is reduced during this stage
    - In the second stage, the compost product is "cured" or finished. Microorganisms deplete the supply of readily available nutrients in the compost, which, in turn, slows their activity
        - As a result, heat generation gradually diminishes and the compost becomes dry and crumbly in texture
        - When the curing stage is complete, the compost is considered "stabilized" or "mature." Any further microbial decomposition will occur very slowly[53]
- During the curing stage, compost is stabilized as the remaining available nutrients are metabolized by the microorganisms that are still present
    - For the duration of the curing stage, therefore, microbial activity diminishes as available nutrients are depleted.
    - This is a relatively passive process when compared to composting stage operations so less intensive methods and operations are used here
- In general, materials that have completed the composting stage are formed into piles or windrows and left until the specified curing period has passed
    - Since curing piles undergo slow decomposition, care must be taken during this period so that these piles do not become anaerobic
        - Curing piles should be small enough to permit adequate natural air exchange
        - A maximum pile height of 8 feet often is suggested
        - **If compost is intended for high-quality uses, curing piles should be limited to 6 feet in height and 15 to 20 feet in width**
- Curing operations can be conducted on available sections of the compost storage or processing area. In general, the area needed for the curing process is one-quarter of the size needed during the composting process
    - **The curing process should continue for a minimum of 1 month**
        - A curing process of this duration will allow decomposition of the composting materials to be completed and soil-dwelling organisms to colonize the compost. It is important to note, however, that curing is not just a matter of time; it also depends on the favorability of conditions for the process to be completed

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[51] http://www.epa.gov/ttnatw01/burn/burnalt1.pdf (pages 41-42)
[52] http://www.epa.gov/ttnatw01/burn/burnalt1.pdf (pages 41-42)
[53] http://www.epa.gov/ttnatw01/burn/burnalt1.pdf (page 16)

- Once the curing process is completed, the finished compost should not have an unpleasant odor
  - Incompletely cured compost can cause odor problems
  - In addition, compost that has not been cured completely can have a high C:N ratio, which can tie up otherwise available nitrogen in the soil and be damaging when the compost is used for certain horticultural applications since immature compost can deprive plants of needed oxygen
    - The C:N ratio of finished compost should not be greater than 20:1[54]

- A physical examination can tell a farmer a lot about compost maturity. Does the compost pile smell bad? If so, it may need oxygen. Temperature and time are other indicators. For example, has the compost in the windrow reached the thermophilic temperature range and remained there for 15 days and five turnings?[55]

Section 4: Health Protection

4.1 *Safeguarding workers*

- **Because food residuals contain human pathogens, fungi and bacteria, safeguarding people in contact with these materials is important**
  - When processing food residuals, workers should wear protective gloves (and eye wear to protect from splatter, if workers are directly in contact with materials)
  - Keep hands away from face--especially the mouth and eyes. Hands should be cleaned with antibacterial wipes or soap after contact with residuals
  - Shoes should be checked for contamination and cleaned as needed
  - **Equipment, too, should be washed after handling food residuals, as bacteria and pathogens can spread into finished piles if touched with contaminated equipment**
  - Don't forget the thermometer used to read temperatures in food residual piles: Wash it after every use, and wash the hands holding it, too
- Living contaminants can easily be managed by taking precautions and enforcing sanitation[56]

4.2 *Importance of proper processes*

- Part of protecting health is proper management of the compost piles
  - Ongoing odors will attract disease-carrying pests, and poorly managed piles may generate temperatures too low to kill pathogens.
  - Piles must sustain temperatures of at least 131ºF to kill living contaminants. Piles should be monitored for temperature and results should be recorded (every few days for the first month; and weekly thereafter)
- **The US Composting Council recommends that facilities handling food residuals meet the time and temperature requirements of EPA's Process to Further Reduce Pathogens (PFRP)**

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54 http://www.epa.gov/ttnatw01/burn/burnalt1.pdf (page 47)
55 http://www.cefs.ncsu.edu/resources/organicproductionguide/compostingfinaljan2009.pdf (page 12)
56 http://compostingcouncil.org/admin/wp-content/uploads/2010/09/BMP-for-FW-to-YW.pdf

- This process, first developed for composting sludge into biosolids, assures that virtually all human pests and pathogens are destroyed
- **For turned windrows: Maintain 131ºF (55ºC) for at least two weeks, with at least 5 turns over that time**
- Not meeting PFRP guidelines means pathogens or pests could be spread via the finished compost.

- Proper management of the compost piles will keep away most pests, and will help ensure that all pathogens are eradicated before finished compost is used[57]

Controlling Pathogens
Pathogens are organisms—such as bacteria, fungi, and nematodes—that incite disease. There are pathogens that are dangerous to humans, animals, and plants. The heat produced during composting helps to control all of these. [58]

Section 5: Permit Compliance

- **For small compost sites such as at UMM, cannot exceed 80 cubic yard per year or will need permit**
    - Note: fifty percent of the volume is lost within a couple of months due to water and carbon loss – this shrinkage factor should be accounted for
- **A temperature of a minimum 131 degrees Fahrenheit for 21days should be maintained**
    - note: weed seeds need at least 7 days of 131 degrees F in order for them to die
-**windrow should be turned 4-5 times during the 21 day period** so that everything is exposed to high temperatures needed to kill pathogens[59]

Section 6: Uses for Compost

- End products of well-run composting system:
    - Humus-like material
    - Heat
    - Water
    - Carbon dioxide
- Used primarily as a soil amendment or mulch by farmers, horticulturists, landscapers, nurseries, public agencies, and residents to enhance the texture and appearance of soil, increase soil fertility, improve soil structure and aeration, increase the ability of the soil to retain water and

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[57] http://compostingcouncil.org/admin/wp-content/uploads/2010/09/BMP-for-FW-to-YW.pdf
[58] http://www.cefs.ncsu.edu/resources/organicproductionguide/compostingfinaljan2009.pdf (page 3)
[59] Black, Ginny. "MPCA Organics Specialist." Personal interview. 13 Feb. 2012.

nutrients and moderate soil temperature, reduce erosion, and suppress weed growth and plant disease[60]

- New rule: compost can be sold off campus but should meet PFRP (liability issue)
    - If someone gets sick, claims it was compost, need Temperature spreadsheet to back us up
    - Student organic gardening club could potentially use compost
    - Material from off-campus can be used
    - Just be sure that total yearly waste is less than 80 cubic yards per year
    - Diary of temperatures, turning etc is important[61]

Compost's Impact on Farm Soils

- Increases soil organic and humic matter, and overall fertility.
- Improves soil structure, aeration, and tillability so it better retains and uses water and nutrients.
- Reduces soil bulk density so plants have deeper root penetration.
- Improves the cation exchange capacity, which increases nutrient availability and reduces leaching
- Leads overall to soil aggregate stability, which allows the soil to function at optimum levels and produce the best yields.

[62]

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[60] http://www.epa.gov/ttnatw01/burn/burnalt1.pdf (page 2)
[61] Black, Ginny. "MPCA Organics Specialist." Personal interview. 13 Feb. 2012.
[62] http://www.cefs.ncsu.edu/resources/organicproductionguide/compostingfinaljan2009.pdf (page 5)

Table 7-3

Potential Users of and Uses for Compost

User Group	Primary Uses for Compost Products	Compost Products	Packaging
Agricultural and Residential Users			
Forage and field crop growers	Soil amendment, fertilizer supplement, top dressing for pasture and hay crop maintenance	Unscreened and screened compost	Bulk
Fruit and vegetable farmers	Soil amendment, fertilizer supplement, mulch for fruit trees	Unscreened and screened compost	Bulk
Homeowners	Soil amendment, mulch, fertilizer supplement, and fertilizer replacement for home gardens and lawns	Screened compost, high-nutrient compost, mulch	Primarily bags, small-volume bulk
Organic farmers	Fertilizer substitute, soil amendment	Unscreened and screened compost, high-nutrient compost	Primarily bulk
Turf growers	Soil amendment for establishing turf,	Screened compost, topsoil blend	Bulk
Commercial Users			
Cemeteries	Top dressing for turf, soil amendment for establishing turf and landscape plantings	Screened compost	Bulk
Discount stores, supermarkets	Resale to homeowners	General screened compost product	Bags
Garden centers, hardware/lumber outlets	Resale to homeowners and small-volume users	Screened compost, mulch	Primarily bags, small-volume bulk
Golf courses	Top dressing for turf, soil amendment for greens and tee construction, landscape plantings	Screened compost, topsoil blend	Bulk
Greenhouses	Potting mix component, peat substitute, soil amendment for beds	High-quality, dry, screened compost	Bulk and bag
Land-reclamation contractors	Topsoil and soil amendment for disturbed landscapes (mines, urban renovation)	Unscreened compost, topsoil blend	Bulk
Landscapers and land developers	Topsoil substitute, mulch, soil amendment, fertilizer supplement	Screened compost, topsoil blend, mulch	Bulk
Nurseries	Soil amendment and soil replacement for field-grown stock, mulch, container mix component, resale to retail and landscape clients	Unscreened and screened compost, composted bark, mulch	Primarily bulk, some bags

[63]

[63] http://www.epa.gov/ttnatw01/burn/burnalt1.pdf (page 7-30)

Section 7: Appendix

7.1 *Temperature Probes*

- **Temperature can be monitored with a dial thermometer that has a stem long enough (36 inches) to reach the interior of the pile**
    - Measurements should be taken at several locations to get a more accurate reading for the pile (or section of windrow) in question
    - When the temperature gets too high (>160°F) the pile should be turned to release heat.
    - Likewise, when the temperature drops below 100°F prior to stabilization, the pile should be turned to introduce more oxygen for the microbes[64]
- Temperature probe websites suggested by Ginny Black:
    - This is the most common: http://www.reotemp.com/composting-products.html
    - http://www.dry-it-out.com/testing-equipment/compost-testing-equipment
    - http://www.compostingtechnology.com/probesandsoftware/windrowmanager/[65]
- Kelli Kish, of Carver County Environmental Services recommendations:
    - **ReoTemp is a very well-known reliable brand to purchase**
        - When we bought our thermometers we purchased them from BenMeadows.com as they were the cheapest at the time
        - You want to make sure the thermometer you purchase goes up to 200 degrees Fahrenheit (or equivalent Celsius if you'll be tracking in C)
        - From the link below we purchased the top item (36" L x ¼" dia.). We did have one thermometer malfunction recently and ReoTemp sent us a new one at no charge. If you're not ordering the guard stick with the ¼" diameter, however, it may be a good idea to upgrade to the 5/16" diameter thermometer as they'll be a bit sturdier than the ones we got. http://www.benmeadows.com/reotemp-compost-thermometers_36817581/?searchterm=reotemp%2bcompost%2bthermometer
        - We purchased the thermometers and the handles separately from ReoTemp's website
            - You can choose to purchase the guards, but they're 2x the price of the thermometer
            - If you do purchase the guards, you'd be fine with the ¼" diameter thermometers.
            - I do recommend purchasing the handles as you are not supposed to push on the head of a thermometer and the handles make it very easy to insert a thermometer into the pile
    - As our site is a little bit of a drive for us and to save staff time we're looking into ordering new thermometers that track the temperature without you there, so when no trucks are coming to the site, we don't have to go there just to take temperatures
        - They're the Compost Data Logger thermometers on the bottom of this page: http://reotemp.com/composting-products.html
    - I would check with MPCA regarding the length of thermometer and how many locations you need to take temperatures from to get the pile average

[64] http://www.mass.gov/agr/programs/compost/docs/Guide_to_Ag_Composting2010.pdf (page 14)
[65] Black, Ginny. "MPCA Organics Specialist." Email. 17 Feb. 2012.

- **We use 3' thermometers at 6 locations and then take the average**….but there currently is no standard of what is required for temp taking. (We've been avoiding asking this question as to not open a new can of worms – but since you're opening a new site it seems logical that you'd ask this question.)[66]

- Anne Ludvik, Specialized Environmental Technologies recommendations:
    - "We use ReoTemp brand thermometers and the guard will help them last longer" [67]

7.2 *Compostable Bags*

- The compostable bag dilemma:
    - Going bagless
        (+) avoid bag purchase cost; food scraps bin clearly identifiable
        (-) more frequent bin washing needed; must drain water into sanitary sewer, not a storm drain, which may increase waste-water disposal costs; potential for increased labor cost
    - Using compostable bags
        (+) simple to use; no increased labor cost; less potential for cont
        (-) more frequent bin washing needed; must drain wash water into a sanitary sewer, not a storm drain, which may increase waste-water disposal costs; potential for increased labor costs
- Kelli Kish, of Carver County Environmental Services recommendations:
    - Carver County uses Bag to Nature throughout the courthouse which generates mostly paper towels from drying hands and small quantities of food waste
    - In terms of stretchability without ripping holes in them, I personally think that the **Bio Tuf** (I think it's Bio Tuf, it might be Al Pack or Natur Bag are the best for lawn and leaf size or 55 gallon brute containers. I would say that Mirel's are the best – but as far as I know they're no longer making bags at this moment
    - I was a bit iffy on the Glad bags as they have kind of a 'cleaner' smell to them at first, but they hold up really well also. I have only tried the Glad mini-kitchen pail size though – but that proves they work well with a lot of heavy wet fruit and veggie material
    - I can definitely say the Husky Eco-Guard are my least favorite of those I've tried. They rip easily, degrade quickly when not used, and moisture leaks through in 1 day[68]
- Anne Ludvik, Specialized Environmental Technologies recommendations:
    - Any BPI Certified Compostable bag will work:
        - http://www.bpiworld.org/BPI-Public/Approved.html
        - I have not come across any really bad ones for a while: the compostable plastic industry has made significant improvements in their products. **The ones with a star seal at the bottom seem to be a little stronger**[69]

[66] Kish, Kellie. "Carver County Environmental Services." Email. 13 April. 2012
[67] Ludvik, Anne. "Specialized Environmental Technologies." Email. 9 April. 2012
[68] Kish, Kellie. "Carver County Environmental Services." Email. 13 April. 2012
[69] Ludvik, Anne. "Specialized Environmental Technologies." Email. 9 April. 2012

7.3 *Bunkers*

- Jersey Barriers is the most often used kind of bunker
  - They are fairly easy to come by (the state, county, or city may have some that are a bit worn and they want to get rid of)
  - Link to jersey barriers: http://www.bing.com/images/search?q=jersey+barriers&view=detail&id=324E2A973591F6D89D6137AAF31642BC87255848&first=0&qpvt=jersey+barriers&FORM=IDFRIR[70]

7.4 *Rain Gardens*

- constructing a rain garden for a compost site is the same as constructing one anywhere else.
  - The links below are the best resources Ginny Black knows of:
    - Blue Thumb: http://bluethumb.org/
    - "How To" Rain Garden Manual: http://www.dnr.state.wi.us/org/water/wm/dsfm/shore/documents/rgmanual.pdf
    - Connecticut Rain Garden http://nemo.uconn.edu/tools/stormwater/rain_garden.htm#DesignConsiderations[71]

7.5 *Record Keeping*

- A log book should be kept for incoming materials: date of delivery, volume and/or weight, type of material, and sources

- Records should be kept as to the mix or "recipe" of raw materials that are used to form compost piles so that adjustments can be made until the optimum recipe is achieved.

- Each pile or windrow will require records indicating: date of pile formation, recipe, temperature readings/dates, turning dates, amount/date of water added, date it was combined with another windrow, date it was moved to the curing pile.

- When windrows are formed over a period of time, flags or stakes can be set into the windrow to differentiate a younger section from an older one. These records will help the compost operator understand the throughput potential of the operation.
- A wind indicator to show which way the wind is blowing is important. Wind speed and direction should be recorded on a daily basis especially when actively turning the compost
- Other records that may be useful include: operator hours, fuel requirements, and equipment repairs[72]
- Windrow/Pile Temperature Monitoring Record sample page twenty-two [73]

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[70] Black, Ginny. "MPCA Organics Specialist." Email. 17 Feb. 2012.
[71] Black, Ginny. "MPCA Organics Specialist." Email. 17 Feb. 2012.
[72] http://www.mass.gov/agr/programs/compost/docs/Guide_to_Ag_Composting2010.pdf (page 14)
[73] http://www.mass.gov/agr/programs/compost/docs/Guide_to_Ag_Composting2010.pdf (page 22)