TITLE: Making Improvements in the Morris Arboretum's Compost

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ABSTRACT:

Presently, the Morris Arboretum has not been able to do any formal composting of its own, despite its many benefits to the soil and the plants that reside in it. Through this project, I have investigated the reasons behind this, as well as taken a closer look at the role of the township in our Materials Handling Area, and how their leaf composting operations work. I researched what considerations must be made in order to produce high quality compost, as well as visited and talked with other institutions to learn about their composting methods and operations to get different ideas about how a similar program should be managed. I developed a concept for how the Arboretum could start composting and how it should be managed in addition to breaking down its start-up and annual costs.

TABLE OF CONTENTS

INTRODUCTION

The ultimate goal of this project is to determine what inputs are required to make 100 cubic yards of compost for the Arboretum to use for compost tea, and as a soil amendment.

Currently, Morris Arboretum does not do any formal composting of its own, even though there is so much potential for the Arboretum to produce it. Making compost would allow the Arboretum to replenish soils that haven't been performing as well as they could. Consider the natural cycle of a plant and its soils- when a plant dies, the nutrients it held are returned to the soil. When the plant is removed, those nutrients are not returned. Though there have been attempts to start composting here in the past with another intern project, the scale of the project was much smaller, and geared mostly toward making compost for compost tea. The smaller bins she created as a result were a great idea, but today, they are not managed. The organic waste generated by the Arboretum currently goes into a pile that is absorbed by the Springfield Township's operation, which I will explain later in this report.

Compost has a wide variety of uses, and has a plethora of benefits. It can be used as a mulch, soil amendment, in compost tea, on highways to absorb runoff in the form of a compost sock, and even be used to generate heat in a greenhouse setting. Another important thing to note is that the act of composting, especially on a large scale, diverts materials away from landfills and returns nutrients that have been previously removed from the soil. Its high organic matter content can amend compacted soils, aid in nutrient and water retention in sandy soils, increase the biodiversity of microbes in soil, enhance fertility of soil and improve root development. ("Why Compost?" n.d.) If the Arboretum made high-quality compost, it would be used most for a soils amendment and for compost tea.

The research of this project contains the following:

- important factors to consider in the making of high-quality compost
- an investigation of the Arboretum's Materials Handling Area and of the Springfield Township's yard waste recycling program
- information and observations of other composting programs at similar institutions
- proposal of a possible system/concept, and estimating its potential costs and benefits to the Arboretum.
- suggestions for the future, for grants and partnerships

CONSIDERATIONS AND METHODS

Part of my research included researching what makes high-quality compost. Through my research I found that making well-balanced, high-grade compost can be 'broken down' into a science. Most people know compost as a little pile in their backyard where they toss their vegetable scraps, eggshells and leaves, which break down into a humic substance over time. These raw materials, or feedstocks, can be made up of many things: food waste, paper, leaves, straw, wood chips, garden clippings, brush (Starbuck, 2010). There are some materials that aren't well suited to composting, as they can cause problems in compost later. These include herbicide/pesticide treated material, weeds gone to seed, and bulb-type weeds, which should be dried out before they are tossed in (Polomski & Doubrava 99).

In order to make well-balanced compost, the amount of different feedstocks can make a difference in the quality and speed of decomposition. Each feedstock has a ratio of carbon to nitrogen content by dry weight (Starbuck, 2010). These can also be called greens and browns. For example, sawdust has a carbon nitrogen ratio of 200:1, but vegetable waste has a ratio of 20:1, meaning 200 pounds of sawdust would have one pound of nitrogen, but only 20 pounds of vegetable waste would have one pound of nitrogen (Starbuck, 2010). Ideally, a compost should be made with an average of 30 carbon to 1 nitrogen by weight (Starbuck, 2010). There are special programs and websites that can calculate this. If there are too many nitrogen-rich feedstocks in a mix, the nitrogen can be lost to atmosphere via ammonia gas as it breaks down, which causes an unpleasant odor (Cooperband, 2002). On the other end, if there is not enough nitrogen, the compost will decompose more slowly (Ward, 2002). Many sources state that adding a high nitrogen source to start up the decomposition process is beneficial, so adding manure, grass clippings, blood meal, or other chemical fertilizers is suggested, since many larger scale composting operations are working with more carbon rich feedstocks (Rosen, Halbach & Mugaas, n.d.).

Once there is a proper carbon-to-nitrogen ratio in the feedstocks, and they are mixed in a pile, bacteria and other microbes start to colonize in the pile. They require moisture, oxygen to breathe, carbon for energy and nitrogen for protein synthesis (Bonhotal & Rollo, 1996). Just like us, they metabolize and release energy in the form of heat, which makes the compost pile hot. Figure A shows the different inputs and outputs of a compost pile. Typically, there are three phases of heating in compost. In the beginning, the compost will climb and hover around 100 degrees Fahrenheit in the mesophilic stage, where the decomposition begins, and eventually gives way to the thermophilic stage, where it reaches over 140 degrees, and heat-loving bacteria take over the pile, getting rid of pathogens and rendering most weed seed unviable (Ward, 2002). Eventually, a compost pile will fall back to the mesophilic stage when the food sources have run out and microbial activity will slow, where it will cool and mature (Ward, 2002). Once this occurs,it gives way to the very last stage, called the curing phase, where the pile finishes stabilizing and decomposing, which usually takes at least a month. (Bonhotal & Rollo, 1996). It is important to point out that the temperature through the pile is not uniform, so it is important to turn the pile and have different parts of the pile exposed to the bacteria and heat (Rosen, Halbach & Mugaas, n.d.). See figure B for a diagram of how heating works in a compost pile.

The frequency of turning, or mixing a pile can affect both weed seed viability and nitrogen and organic matter content. Piles that are turned more often will have less weed seed viability, but will also have lower nitrogen and organic matter, since nitrogen gas escapes when a pile is being turned ("Why Compost?" n.d.). However, turning the pile is important for rejuvenating the oxygen supply and exposing new surfaces to decomposition.

Another aspect to consider in making compost is moisture. 40-60% moisture is ideal for optimum microbial activity; less than that can cause some microorganisms to go dormant (Bonhotal & Rollo, 1996). Above 60% moisture and nutrients can leach, and anaerobic bacteria may become dominant, slowing decomposition and creating a bad smell (Ward, 2002). A simple way to test this is the squeeze test-- take some compost in your hand and it should feel like a damp sponge, with one or two drops of water coming out when you squeeze it (Bonhotal & Rollo, 1996).

Keeping an eye on the moisture content during dry spells and adding water might be necessary, and in wet weather, turning piles more often helps dry the piles out (Bonhotal, Shayler, & Schwarz, 2007). Moisture content is also important for weed seed destruction, as studies have shown that seeds can remain viable in higher temperatures for longer, as opposed to seeds that were exposed to moisture, or were imbibed. (Zaborski, 2013)

Because the microbes that decompose feedstocks are aerobic, oxygen is vital to the process. Having free air space allows air flow and allows oxygen to occupy open pore space. Figure C gives a good visual of differing pore space in compost. Too little oxygen will result in slow, smelly, anaerobic decomposition (Cooperband, 2002). Adding a bulking agent might help increase oxygen via pore space (Bonhotal & Rollo 1996). Particle size also factors into this; while smaller particles have more surface area for microbes to break down, they may also become compacted, reducing air flow. Meanwhile, larger particles take longer to break down (Rosen, Halbach & Mugaas, n.d.).

Different sources state varied ideal temperatures and durations of those temperatures for the best results and elimination of viable seed, though many state that the temperatures in a pile of compost should rise, and stay between 130-160 degrees for at least 15 days straight (Rosen, Halbach & Mugaas, n.d.). Regulation from the USDA states that a pile must be turned 5 times in the first 15 days of a pile's creation to eliminate pathogens (Zaborski, 2013). Piles should be turned when they reach a certain temperature, between 140 and 150 degrees to add oxygen and cool the pile ("Why compost?", n.d.). Otherwise, temperatures can get too high and actually kill the microbes in the compost pile, and if the pile is also dry, it could actually combust (Rosen, Halbach & Mugaas, n.d.). When temperature of a pile creeps up too high, adding water while turning a pile can help cool it down to optimal temperatures (Ward, 2002). When a batch of compost is finished, it no longer heats up when it is turned, and remains within 10 degrees of the ambient temperature (Ward, 2002). Its contents are dark and pleasant smelling, and are generally ½ to ⅓ the original volume (Rosen, Halbach & Mugaas, n.d.)

CURRENT SYSTEM

The Springfield Township has an agreement with the Morris Arboretum to use the Materials Handling Area to process leaves and yard waste as part of their fall cleanup program. They collect the bagged yard waste, mostly consisting of leaves, and dump it at the site starting the second week of September through December (D. Sirianni, personal communication, Dec 3 2014). The Arboretum also contributes their pile of organic material that builds up throughout the summer with weeds, brush, and other biomass, and once the township has a sizeable amount of material, it is tub-ground into another substantial pile. The pile becomes larger, and is made taller through driving on top of the pile while pushing material using a front-end loader. However, in the process of driving on to the piles, the piles compact, leaving less free air space for oxygen. Once all the material has been ground up, the material is then moved into large windrows.

According to Don Sirianni, the director of public works at Springfield Township, the piles are turned every three weeks, depending on weather and workload, though there is no evidence that this has been done more than once since mid-January. Turning occurs through March or April and the product is sometimes ground once more and is brought to the area where residents can pick up the material. To my knowledge, the township's only monitor temperature (D. Sirianni, personal communication, Dec 3 2014). Not considering or monitoring the other factors discussed earlier can jeopardize the quality of the product being made, and will not create a quality product that the Arboretum is currently seeking.

The product that the township makes is not managed very closely, and because the area is constantly wet and the piles are compacted, they become anaerobic. In addition, the water holding capacity is much lower than is ideal, and is not uniformly broken down. Because the feedstock is coming from residents in bags, it is hard to know the origin and content of their yard compost, and because it isn't really managed closely, it is hard for the horticulture staff to trust. The horticulture staff prefers not to use it, as they claim that they have had issues with weeds coming up where they have used the compost in places they previously didn't have weeds before.

Another important factor to consider is our own café. Using their kitchen scraps could be a great addition to our compost pile, but since there isn't any formal operation in place, they have their compost taken away by Bennett Compost, a local company who picks up compost from businesses around Philadelphia.

SITE LIMITATIONS

The Arboretum's site is north of the Horticulture Center and next to the Quercetum. For some time now, there has been major concern from the horticulture staff about the township's operation encroaching into the Quercetum. The area is bare soil and has a tendency to get standing water and ruts. Puddling in an area that has compost can promote anaerobic conditions. Presently, there is recycled asphalt that functions as pavement in some areas, but it is no longer allowed by the DEP because it is oil derived. Another issue with the asphalt is the risk that it could end up in the compost product.

There is also the issue of the weed seeds that contaminate the product, which is one of the big reasons why the horticulture staff doesn't use it. The site surrounding the pile must be more actively managed; that is, mowing or string trimming down the weeds through the seasons to avoid weeds from flowering and maturing and blowing seed into the piles. Ensuring that compost piles get hot enough and are *uniformly* 'cooked' will also ensure that weed seeds are no longer viable, if they remain in the piles.

Perhaps the biggest current limitation is that there is no one at the Arboretum who manages the Arboretum's share of waste, so it is currently absorbed into the township's pile. The reason for this is that there is simply no one for the job--the staff at the Arboretum is busiest when they are generating the most organic material. After investigating our Materials Handling Area, I decided to look to other institutions for inspiration on how we could solve the problem.

CASE STUDIES

My research led me to investigate the methods of four different compost facilities at Mount Auburn Cemetery, in Boston, Longwood Gardens, Scott Arboretum at Swarthmore College, and Weavers Way Co-op at W.B. Saul, a nearby agricultural high school. All institutions have their own inputs, methods, and uses for their compost.

I had heard from a professor about Mount Auburn's recently renovated composting system and decided to look into it. I interviewed the compost manager, Paul Walker, and discovered they use a concrete bin system, with nine different bins, four of which are used to make compost. They use grass clippings, funeral flowers, and shrub pruning for greens, and leaves, wood chips, and hay for the browns (Friends of Mount Auburn, 2011). About once a week, depending on feedstock amounts, the greens are put into a mixing bin with the other materials to start a new batch using a compact articulating loader. It is turned every three days for two weeks, after which it is moved elsewhere, where it is mixed once every two weeks, then once a month. They actively make compost from May to October, totaling about 100 yards annually. They used to make two varieties of compost but now make only one, since they were very similar in composition (P. Walker, Personal Communication, Oct. 6, 2014). They have many uses for the product, in lawns on grass seedlings, at the nursery, as a general soil amendment or top dressing, to make compost tea, and for potting mix. It is regularly tested for microbial content to ensure quality. They also make mulch consisting of 75% chips and 25% leaves, which they use around the grounds. The cemetery is 175 acres, roughly similar to our size (Kwiatkowski, 2013).

At the Scott Arboretum, I was shown around by Nicole Selby, who manages the area in addition to being part of their horticulture staff. There is a 1.5 acre pad shared by the Arboretum and two local townships, and use of the pad by each party varies within the seasons. The townships own a self-propelled scarab turner and refuel and maintain it. During the fall and winter, the townships split the pad down the middle and share use of the windrow turner, turning windrows twice a week through the winter, and bringing it elsewhere for residents to take when it is finished. Meanwhile, the Arboretum's collection of brush is put on the side of the pad to accumulate over the winter. During late spring and summer, the Arboretum uses the pad for composting, making three or so small batches, totaling to about 100 yards annually. The Arboretum's piles are monitored and turned regularly keeping them between 130 and 150 and under 160 (N. Selby, Personal communication, Oct. 9, 2014). The compost is not monitored for moisture or formally tested, but Selby takes time to observe it under a microscope for microbial activity. The pad is surrounded by grass and bare soil where weed management is taken care of by brush hogging to prevent thistle, in addition to prohibiting certain noxious weeds from going into the pile (N. Selby, Personal communication, Nov. 5, 2014). Their composting pad is in a separate area of campus that must be accessed through a public road, so the Arboretum also has a small holding area on campus with concrete bins separating raw green and brown material in addition to providing finished compost and woodchips. They use a skid steer in this area, which proves useful in their holding area for loading their work vehicles and making the area neat.

Though Longwood is a much larger facility than Morris, I thought it would be helpful to see their Materials Handling Area. Longwood makes about 2,500 cubic yards of compost annually, in addition to mulch and leaf mold. Matt Taylor, the research manager, oversees the management all of organic material from their property including food waste, and manure from a few farms nearby. There are seven collection sites on Longwood's grounds from which materials are brought to their processing area. This is handled by two full-time and one part-time staff dedicated to the composting operation.

The area is between five and six acres, with one acre dedicated to the windrows, surrounded by agricultural land and a wetland with a riparian buffer in the distance. Weeds grow in the surrounding area but the piles are actively maintained and turned (M. Taylor, Personal communication, Oct. 21, 2014). This area also includes a few buildings where topsoil is stored and managed. They have a large pile containing larger brown materials that are processed through a tub grinder once a year to make mulch. There is also a separate pile for arborist wood chips and a separate area for leaf processing. Their compost, however, is a mixture of plant and food waste, wood chips and manure. The feedstocks are mixed in a vertical mixer to make the windrows which are later turned with loader and a Sandberger PTO turner, of which daily temperature readings determine the turning frequency (M. Taylor, Personal communication, Oct 21 2014). Windrows are typically finished in 10 to 12 weeks, and are then screened. Each finished pile of compost undergoes various tests: a compost maturity test, which gauges the activity and stability of the product, a pH and electrical conductivity (EC) test, and seed germination tests. An outside laboratory tests for metals and other elements and periodic microbiological diversity testing (M. Taylor, Personal communication, Oct. 21, 2014).

The closest resource I visited was the WB Saul High School of Agricultural Sciences in Roxborough, which has a compost program in partnership with Weavers Way Co-op, the Philadelphia Zoo, and Bennett Compost, at the school’s farm site, where the dairy cows reside. I toured around with the manager, Scott Blunk, who started the partnership between the school and the Co-op. I discovered that their inputs vary greatly from ours, being primarily animal manure and bedding and food waste. Food comes from the Co-op and Bennett Compost contributes collections from local restaurants and coffee shops; meanwhile manure comes from their own dairy cows and the zoo, which drops off about a ton daily (S. Blunk, Personal Communication, Nov 3 2014). Because of their steady stream of several tons of feedstocks, composting is a year-round task. They work under a windrow system on a two acre area. The surrounding area is graze land for cows and has weeds that are mowed regularly. Before they are put into 6x3x140 foot windrows, they are stored for a short time in a large pile. Windrows are turned frequently because of their high nitrogen content, and are monitored for moisture and temperature. Their primary equipment includes a John Deere loader, a Sandberger PTO turner and a vibratory screener. The compost program is a great resource in teaching the students about chemistry, microbiology, sustainability, and the importance of using nature’s resources responsibly. Students assist in testing the compost and areas surrounding as well as learning about the biology of compost, as well as screen and bag the compost to sell (S. Blunk, Personal Communication, Nov 3 2014.

MANAGEMENT PLAN

After making observations and learning more about the different places I visited, it helped me develop different ideas about what the Arboretum could do to efficiently compost its organic material. My ideas came mostly from the Scott Arboretum and the Mt. Auburn Cemetery, since both locations are similar sized institutions in relation to the Morris and both make approximately 100 yards of compost annually, but do it in totally different ways. While the Scott Arboretum shares their area with townships like we do, I decided that modeling after both institutions use of bin systems would work out best here at the Morris, since there are already bins at our materials handling site that could be reconfigured for a composting operation.

The bins that are currently being used to keep firewood would be ideal for composting. By expanding the size of the pad--separating the two bins into four smaller bins--the Arboretum could have a designated area for composting. A new structure would have to be made to hold the large stumps and firewood for the mechanic's shop. Each of the four bins would hold a certain material: one to hold greens, one for browns, one for actively decomposing compost, and one for finished compost. Each bin would be labeled, and new and current employees would be taught how to separate their organic materials, and where to put different items. Certain waste materials should be omitted from the piles, including material with pesticide or herbicide residues, thistle gone to seed, pinellia, and stumps (which could dull the chipper blades). The green bin would hold herbaceous plant material, grass clippings, flowers, and kitchen scraps from the café and the brown bin would hold woody, dry materials like brush and branches. As the brown bin fills up, the contents would be chipped and put in the wood chips pile. As the green bin fills, a new batch should be made in the third bin, using the two-parts brown material and one-part green material. New piles would be monitored and turned as temperatures spike. Depending on how intensively managed it is, a batch could be done in as little as 12 weeks, allowing for multiple batches to be made throughout the season. Over the winter, there is less green material, so incoming brown material can be allowed to pile up until spring, or made into wood chips. In this way, the Arboretum can get compost in smaller batches through the year to use for soil amending and compost tea around the grounds. The area surrounding the bins would have to be managed for weeds through brush hogging or string trimming, and woodchip piles should also be turned so that they can 'season', in addition to keeping the area neat.

It is important to realize that the township's partnership is valuable and benefits us, as it allows us to dispose of materials we could not process, but working directly with the township for a full composting program would not be feasible for multiple reasons. The township's primary goal is to process the large volume of leaves they receive from residents, successfully diverting them from a landfill. They process a high volume of dry materials during a time when the Arboretum would not be able to supply sufficient nitrogen rich ingredients for them to make a well balanced compost. They work strictly seasonally based on when they have the time, and aren't around during the time of year when the Arboretum is generating the most organic material. If the Arboretum wanted to make high-quality compost and work with the township, there would have to be major reconstruction of the area to avoid future puddling and ruts or even move the area altogether, which would be very expensive. The Arboretum could feasibly make compost in a smaller area that already exists making it more cost effective. To see a cost breakdown, please see Appendix A.

In order to process and turn a pile of compost, the New Holland loader may suffice, though a skid steer would be more desirable and more efficient, as well as a great tool to use in other areas of the garden. A skid steer would make things much easier, as it is more compact, and would be a better fit for the work than our current front-end loader. And while there are less expensive, less powerful skid steers, purchasing one that has the load capacity or ability to pick up and move a full pallet of fertilizer (50 bags at 50 lbs. ~ 2500 lbs.) would give it another purpose (since the loader cannot fully fit into the fertilizer room). It would also be handy for loading golf carts with mulch and compost, since the loader can be quite tricky. Looking past the initial purpose for the skid steer, there are some add-on options that are strongly suggested for it to be equipped with for other uses. For example, adding Heat/AC in the cab to allow for working in an enclosed environment in summer heat and winter snow, adding Turf/Floatation tires so the machine can be driven on lawns without leaving ruts, and adding a two-speed transmission to speed up the journey from farm to garden 7.1mph/12.3mph. The skid steer would benefit the whole garden, not just by aiding compost production but with other uses as well.

The Arboretum would also require someone to manage the compost. Asking around at the other institutions I investigated and visited, I estimate that managing and processing compost at the Arboretum would take a maximum 25 hours weekly, for the growing season (April through October). This person would be in charge of managing weeds, organizing and neatening the piles, monitoring and turning the piles, chipping brush, and retrieving kitchen compost from the café. Having someone to monitor and carry out this process correctly would allow the Arboretum to make a high-quality, closed-loop composting system.

CONCLUSION/FUTURE CONSIDERATIONS

The idea of making high-quality compost at the Arboretum has been around for a while, but has not come to fruition because no one has been able to take it on as a project, nor has anyone determined its cost, or figured out a manageable size for it. In this project, I have outlined different topics to consider in the making of compost, developed a reasonable concept plan, and determined its potential start-up and annual costs to the Arboretum, from labor hours and area modifications to skid steer purchasing prices and maintenance.

In addition to making a soil amendment to use around the garden and providing a source for compost tea, the compost would finally enable horticulturists to improve the soil and the plants living in them, without having to leave the Arboretum grounds.

Most botanical gardens today are composting their organic materials in some form or another, and it is important to consider that having a compost program could easily be used for marketing in promotion of the Morris Arboretum as a sustainable establishment--along with having a LEED certified horticulture center, and using IPM in the garden--adding a formal compost program is a great next step to being sustainable. In addition, the Arboretum can also use this program as a teaching tool--employing it for educational purposes to teach people of all ages about the benefits of composting, and the science of decomposition.

In the future, applying for Penn's Green Fund grant would be a great way to start raising funds to initiate the program. Arrangements could be made with a nearby farm to add manure to the compost, which is a recommended soil amendment for roses, and would be a great addition to the finished product. The current pad can also be added to for more bins, and it has also been discussed with the Arboretum café to work with them, composting their kitchen scraps.

In the near future, I hope that this research will be useful in helping the Arboretum take control of its organic materials and create a product that horticulture staff can depend on in the gardens. By making a few investments, composting here a feasible endeavor that will not only benefit the garden, and the environment, but it will put the Morris on a higher level of sustainability that has become somewhat of an industry standard today.

REFERENCES

Bonhotal, J., Shayler, H., Schwarz, M. and Wellin, L. (2007) Compost fact sheet #3: Improving and Maintaining Compost Quality. Cornell Waste Management Institute. Retrieved from http://cwmi.css.cornell.edu/compostfs3.pdf

Bonhotal, J. and Rollo, K. (October 1996). Compost... Because a Rind is a Terrible Thing to Waste! Cornell Waste Management Institute. Department of Crop and Soil Sciences. Retrieved from http://cwmi.css.cornell.edu/compostbecause.pdf

Cooperband, L. (March 2002). The Art and Science of Composting: A Resource for Farmers and Compost Producers. University of Wisconsin- Madison Center for Integrated Agricultural Systems. Retrieved from Friends of Mount Auburn. (November 2011). Composting at Mount Auburn. [blog post]. Mount Auburn Cemetery Oct 2014. Retreived from http://mountauburn.org/2011/composting-at-mount-auburn-2/

Kwiatkowski, P. (May 2013) Composting: Addition by Subtraction. Ecological Landscaping Alliance. Oct 2014. Retrieved from http://www.ecolandscaping.org/05/composting-compost-tea/composting-addition-by-subtraction/

Polomski, B. and Doubrava, N. (June 1999). Clemson University. Retrieved from http://www.clemson.edu/extension/hgic/plants/other/compost_mulch/hgic1600.html

Rosen, C., Halbach, T.R., Mugaas, R. Composting and Mulching: A Guide to Managing Organic Yard Wastes. University of Minnesota Extension. Retrieved from http://www.extension.umn.edu/garden/yard-garden/soils/composting-and-mulching-guide/

Starbuck, C. J. Making and Using Compost. University of Missouri Extension. Retrieved from http://extension.missouri.edu/p/g6956

Ward, M. M. (2002). Composting: A Beginner's Guide. The Robert A. Macoskey Center for Sustainable Systems Education and Research at Slippery Rock University of Pennsylvania. Retrieved from http://www.sru.edu/academics/colleges/ches/macoskey/Documents/Composting%20-%20A%20Beginners%20Guide%20%28web%29.pdf

Why compost? *Compost Fundamentals.* Washington State University Whatcom County Extension. Retrieved from http://whatcom.wsu.edu/ag/compost/fundamentals/index.htm

Zaborski, E. (July 2013) Composting to Reduce Weed Seeds and Plant Pathogens. eXtension. Retrieved from http://www.extension.org/pages/28585/composting-to-reduce-weed-seeds-and-plant-pathogens#.VOzMhixUWex

ADDITIONAL RESOURCES:

Green fund grant: http://www.upenn.edu/sustainability/get-involved/green-fund
Local farm: http://www.ashfordfarm.com/horses/

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There are so many people I have to thank from this project, and I would not have been able to complete it without their help. First, I would like to thank Horticulture Section Leader, Kate Deregibus, my advisor for this project, for helping me 'break it down' and keep things in perspective. I would also like to thank Chief Horticulturist, Vince Marrocco for his experience with the history of the Materials Handling Area and Mechanic, Keith Snyder for answering all of my mechanical questions. I am also grateful for the opportunity to meet with and talk to Matt Taylor, Nicole Selby, Scott Blunk and Paul Walker, to learn more about composting on a larger scale.

FIGURES AND APPENDICES

Figure A: Diagram of inputs and outputs

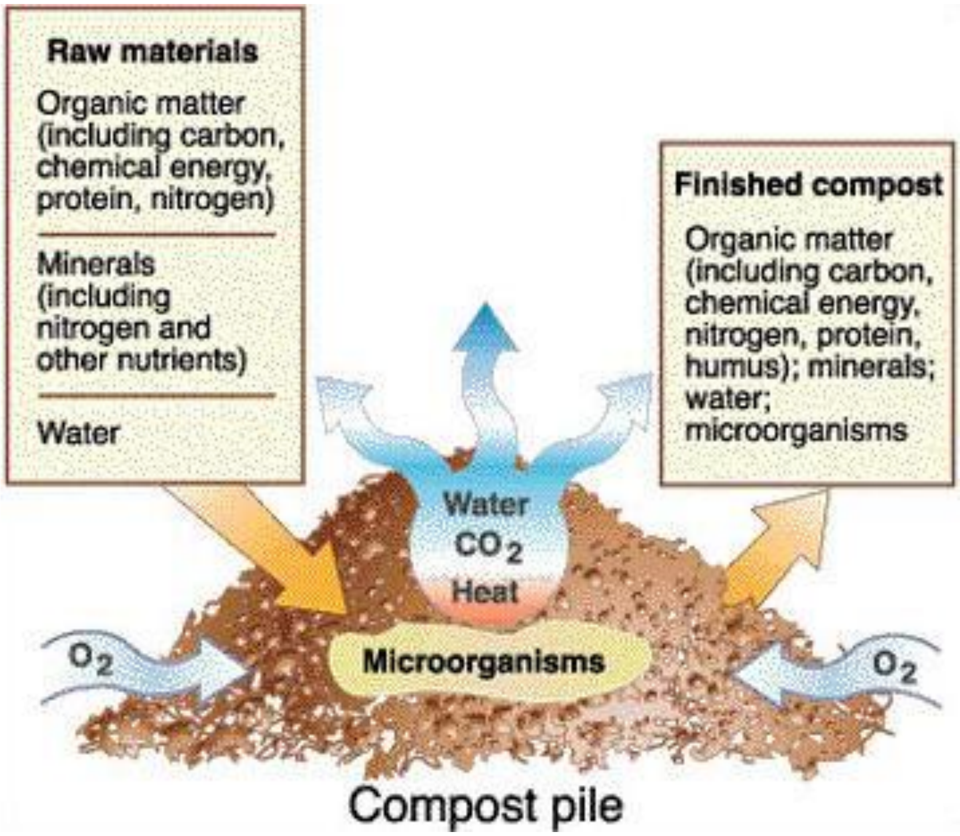


Figure B: Diagram showing heat in a compost pile

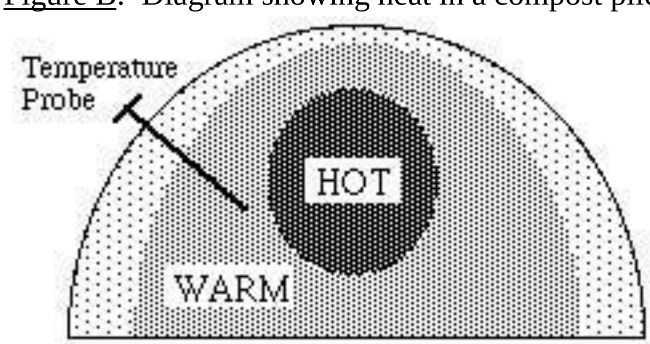
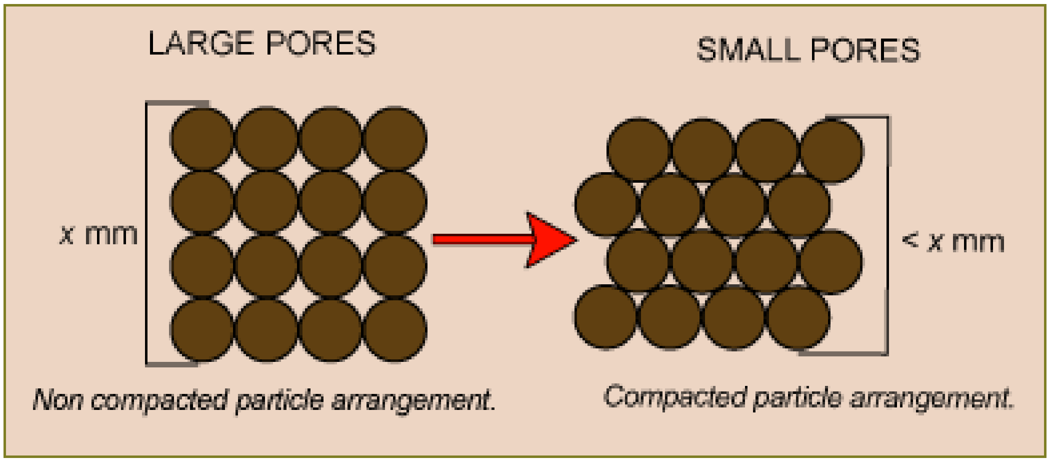


Figure C: Diagram showing pore space



Appendix A: Breakdown of costs, see attached document

Compost Program Start-Up and Annual Costs			
Morris Arboretum of the University of Pennsylvania			
Start up costs:			
Compost Pad addition	Addition of 6'x 22' of concrete and moving concrete dividers.	$ 6,200.00	
Skid steer Bobcat S650	Base	$ 45,459.00	
	Heat/AC Cab	$ 4,549.00	prices based on 2010 numbers
	2 Speed, bucket assist	$ 1,940.00	prices based on 2010 numbers
	Flotation tires	$ 882.00	
	General purpose bucket	$ 1,065.00	
	Bucket Spill Guard	$ 245.00	
	Bolt on cutting edge, bucket	$ 189.00	
Total		**$ 54,329.00**	

Annual costs						
		Frequency	Cost	Annual service amount	Annual Cost	Details
Maintenance	Oil 2.5 gal	100 hrs	$ 40.00	2.5	$ 100.00	
	Oil filter	100 hrs	$ 12.33	2.5	$ 30.83	
	Fuel filter	250 hrs	$ 49.88	1	$ 49.88	
	Inner air filter	when needed	$ 55.07	1	$ 55.07	
	Outer air filter	when needed	$ 28.21	1	$ 28.21	
	Hydraulic cartridge filter-cooling fan motor	500 hrs	$ 39.57	0.5	$ 19.79	
	Oil hydraulic assembly filter	1000 hrs	$ 49.04	0.25	$ 12.26	
	Hydraulic fluid 2.5 gal	1000 hrs	$ 38.86	0.25	$ 9.72	
	Antifreeze 2.5 gal	every 2 yrs	$ 14.39	0.5	$ 29.15	3 gal tank
	Grease	10 hrs	$ 3.89	25	$ 97.25	
	Drive belt	250 hrs	$ 151.06	1	$ 151.06	
	Alternator belt	as needed	$ 61.53	1	$ 61.53	
	Battery	as needed	$ 17.97	0.25	$ 4.50	
					$ 649.25	
Staff	25 hrs/week @$12.00/hr for 6 months				$ 7,200.00	
Diesel	10 hrs/week for 24 weeks at $11.20/hr				$ 2,688.00	*
Total					**$ 10,537.25**	
* Estimated annual usage of skid steer 240 hrs/ year						
Additional attachments:						
Forklift frame with forks costs $805.						
A 72” seeder costs about $ 7000.						
Snow Blades come in a variety of widths and range from $ 2000 to $ 4000.						
A snow pusher around $ 3000 to $ 3300.						
A v-blade snowplow comes in a variety of widths and ranges from $ 3900 to $ 4200						
Snow blowers come in a variety of widths and capacities and range from $ 4100 to $ 7000.						
Angle Broom for snow & other uses comes in 68” and 84” widths and ranges from $ 5200 to $ 6000.						
Tree Spade attachments come in widths from 24” to 36” and range from $ 8800 to $ 10000.						