Appendix 2.2 Evaluation of Compost Options

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Introduction

The composting of organic solid waste can help decrease the amount of solid waste that must be sent to a landfill or incineration, thereby reducing disposal costs. Composting also yields a product that can be used by farmers, landscapers, horticulturists, government agencies, and property owners as a soil amendment or mulch. The compost product improves the condition of soil, reduces erosion, and helps increase water retention.

For the biological treatment of organic materials the application of composting is the most prevalent technology. In Europe it is estimated that 80 million tons per year of organic materials are composted at more than 3500 plants.

Composting is a biological process in which organic material is decomposed by the action of microorganisms. Composting relies on a natural process that results from the decomposition of organic matter by microorganisms. Decomposition occurs wherever organic matter is provided with air and moisture.

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 drier and crumbly in texture. When the curing stage is completed, the compost is considered “stabilised” or “mature.” Any further microbial decomposition will occur very slowly.

Factors influencing the composting process

Microorganisms are essential to composting, and the environmental conditions that affect microbial activity maximise the rate of composting. Microbial activity is influenced by oxygen levels, particle sizes of the feedstock material, as well as nutrient levels and balance, moisture content, temperature, and acidity / alkalinity (pH). Any changes in these factors are interdependent; a change in one parameter can often result in changes in others. These factors and their interrelationships are discussed briefly below:

(i) Oxygen

Microorganisms important to the composting process require oxygen to break down the organic compounds in the composting feedstock. Without sufficient oxygen, these microorganisms will diminish. This occurs when the oxygen concentration in the air within the pile falls below 5 to 15 percent (ambient air contains 21 percent oxygen). 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, or by using forced aeration systems.

The amount of oxygen that needs to be supplied during composting depends on:

- The stage of the process - Oxygen generally needs to be supplied in the initial stages of composting; it usually does not need to be provided during curing.

- The type of feedstock - Dense, nitrogen-rich materials (e.g. grass clippings) will require more oxygen.
- 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. For this reason, the feedstock should not be shredded too small before processing.
- The moisture content of the feedstock - Materials with high moisture content (e.g. food scraps, garden trimmings) will require more oxygen.

(ii) Particle Size

The particle size of the feedstock affects the composting process. The size of feedstock materials entering the composting process can vary significantly. 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 particles surface is exposed to direct microbial action and decomposition in the initial stages of composting. Smaller particles within the composting pile also result in a more homogeneous mixture and improve insulation. Increased insulation capacity helps maintain optimum temperatures in the composting pile. At the same time, however, the particles should not be so small as to compact too much, thus excluding oxygen from void spaces, as discussed above.

(iii) Nutrient Levels and Balance

For composting to proceed efficiently, microorganisms require specific nutrients in an available form, adequate concentration, and proper ratio. The essential macronutrients needed by microorganisms in relatively large amounts include carbon (C), nitrogen (N), phosphorus (P), and potassium (K). Microorganisms require C as an energy source. They also need C and N to synthesise proteins, build cells, and reproduce. P and K are also essential for cell reproduction and metabolism. (In a composting system, either C or N is usually the limiting factor for the efficient decomposition.

Composting organisms also need micronutrients, or trace elements, in minute amounts to foster the proper assimilation of all nutrients. The primary micronutrients needed include boron, calcium, chloride, cobalt, copper, iron, magnesium, manganese, molybdenum, selenium, sodium, and zinc. While these nutrients are essential to life, micronutrients present in greater than minute amounts can be toxic to composting microorganisms.

The C:N ratio is a common indicator of the availability of compounds for microbial use. The measure is related to the proportion of carbon and nitrogen in the microorganisms themselves. High C:N ratio (i.e. C:N ratio greater than 35:1) inhibit the growth of microorganisms that degrade compost feedstock. Low C:N ratios (i.e. C:N ratio less than 25:1) initially accelerate microbial growth and decomposition. With this acceleration, however, available oxygen is rapidly depleted and anaerobic foul-odour 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.

(iv) Moisture

The moisture content of a composting pile is interconnected with many other composting parameters, including moisture content of the feedstock, microbial activity within the pile, oxygen levels, and temperature. Microorganisms require moisture to assimilate nutrients, metabolise new cells, and reproduce. They also produce water as part of the decomposition process. If water is accumulated faster than it is eliminated via either aeration or evaporation (driven by high temperatures), then oxygen flow is impeded and anaerobic conditions result. This usually occurs at a moisture level of about 65 percent.

Water is the key ingredient that transports substances within the composting mass and makes the nutrients physically and chemically accessible to the microbes. If the moisture level drops below about 40 to 45 percent, the nutrients are no longer in an aqueous medium and easily available to the microorganisms. Their microbial activity decreases and the composting process slows. Below 20- percent moisture, very little microbial activity occurs.

(v) Temperature

Temperature is a critical factor in determining the rate of decomposition that takes place in a composting pile. If temperatures are less than 20^{o}C, the microbes do not proliferate and decomposition slows. If temperatures are greater than 59^{o}C, some microorganisms are inhibited or killed, and the reduced diversity of organisms results in lower rates of decomposition.

(vi) Acidity/ Alkalinity (pH)

Bacteria prefer a pH between 6 and 7.5. Fungi thrive in a wider range of pH levels than bacteria, in general preferring a pH between 5.5 and 8. If the pH drops below 6, microorganisms, especially bacteria, die off and decomposition slows. If the pH reaches 9, nitrogen is converted to ammonia and becomes unavailable to organisms. This too slows the decomposition process.

<u>Composting Methods</u>

Microorganisms decompose the readily available nutrients present in the feedstock during composting. Because most of the actual change in the feedstock occurs during this stage, the most intensive methods and operations tend to be used here. Compost processing can occur in simple environments that are completely subject to external forces or in complex and highly controlled environments. The composting methods currently employed are (in order of increasing complexity):

- Passive piles
- Turned windrows
- Aerated static piles
- In-vessel systems

(i) Passive Piles

Although this method is simple and generally effective, it is not applicable under all conditions or to all types of materials. Composting under these conditions is very slow and is best suited to materials that are relatively uniform in particle size. Passive piles can be used for composting yard trimmings or animal manure, however they are not suitable for MSW as it cannot be guaranteed that all of the material will reach a high enough temperature to sterilise the waste, meaning that the compost produced may not be suitable for use as a growing medium. Further there is a propensity for odour and vermin problems.

Passive piles require relatively low inputs of labour and technology. They consist of piles of composting material that are tended relatively infrequently, usually only once each year. Tending the piles entails turning them (i.e. physically tearing down and reconstructing them). Such an effort requires only a few days use of personnel and equipment, making this a relatively low-cost composting method.

Several disadvantages are associated with passive pile methods. Unlike more intensive composting processes that can produce a finished product in a few weeks to a few months, passive piles can require over 1 year for the composting process to be completed and therefore require a large footprint. In addition, the minimal turning of passive piles results in the formation of anaerobic conditions, similar to the conditions in a landfill, which means that methane is produced, which is a greenhouse gas. Also, when piles are eventually turned (especially for the first year or two of the process) significant odours are released. Passive piles consequently cannot be placed in densely populated areas, and a large buffer zone is recommended between residents and composting operations. Finally, large, untended piles have the potential to overheat and combust, creating a possible fire hazard.

(ii) Turned Windrows

Turned windrows are a widely used method for composting yard trimmings and farm waste. This method generally is not appropriate, however, for MSW as it cannot be guaranteed that all of the material will reach a high enough temperature to sterilise the waste, meaning that the compost produced may not be suitable for use as a growing medium. As the composting is not enclosed there are also odour issues.

Turned 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 completing of the composting process for yard trimmings in approximately 3 months to 1 year.

Turned windrow operations generally can be conducted outdoors. To increase the operator's ability to control composting conditions, however, windrow can be placed inside a shelter. Leachate problems should be minimised by constructing windrows on firm surfaces surrounded by vegetative filters or trenched to collect runoff.

Run-on controls also are helpful as is careful balancing of the C:N ratio. 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.

(iii) Aerated Static Piles

Aerated static piles, sometimes called forced aeration windrow, are a relatively high-technology approach that can be used to compost both yard trimmings and MSW. This approach is effective when space is limited and the composting process must be completed quickly. In this method, piles or windrows are placed on top of a grid of perforated pipes. This maintains aeration in the compost pile, minimising the need for turning. In some operations, the pipes are removed after 10 to 12 weeks of composting and the piles or windrows are then turned periodically.

To ensure that decomposition proceeds at high rates, temperature, moisture and oxygen levels must be closely monitored and maintained with aerated static pile composting. Aeration management depends on how the blower is controlled. The blower can be run continuously or intermittently. Continuous operation of the blower permits lower air flow rates because oxygen and cooling are supplied constantly; however, this leads to less uniform pile temperatures. Intermittent operation of the blower is achieved with a programmed timer or a temperature feedback system. Timers are a simple and inexpensive method of controlling blowers to provide enough air to satisfy oxygen requirements and control temperatures. This approach does not always maintain optimum temperatures, however. A temperature feedback system does attempt to maintain optimum pile temperatures, for example, within the range of 54 ^{o}C to 60 ^{o}C.

In general, the aerated static pile method is best suited for granular materials that have a relatively uniform particle size of less than 1.5 to 2 inches in diameter. This is because large or wet materials and materials of diverse sizes have a tendency to clump. Clumping constricts air flow through the piles, leads to short circuit of air pumping equipment, produces anaerobic pockets, and otherwise limits the rate of decomposition. Aerated static piles are commonly used for composting wet materials (such as biosolids), it is sometimes a requirement to spray the piles with additional water as the material can dry out through the aeration process. Often the aerated static piles are kept indoors so that odour and moisture can be managed.

(iv) In-Vessel Systems

In-vessel systems are high-technology method in which composting is conducted within a fully enclosed system. All critical environmental conditions are mechanically controlled with this method, and, with most in-vessel systems, they also are fully automated. These systems are rarely used to compost yard trimmings because it is expensive to maintain this degree of control. More and more facilities are selecting in-vessel systems for their MSW composting program. An in-vessel system can be warranted for MSW if: 1) the composting process must be finished rapidly, 2) careful odour and leachate control are a priority, 3) space is limited, 4)sufficient resources are available.

In-vessel technologies range from relatively simple to complex systems. Two broad categories of in-vessel technologies are available: rotating drum and tunnel systems. Rotating drum systems rely on a tumbling action to continuously mix the feedstock materials. The drums typically are long cylinders, approximately 9 feet in diameter, which are rotated slowly, usually at less than 10 revolutions per minute. Oxygen is forced into the drums through nozzles from exterior air pumping systems. The tumbling of the materials allows oxygen to be maintained at high and relatively uniform levels throughout the drum. The promotional literature for rotating drums indicates that composting material must be retained in the drums for only 1 to 6 days. Complete stabilisation of the composting material is not possible within this timeframe, however, and further composting and curing of from 1 to 3 months is necessary.

Tunnel systems are usually constructed of concrete with aerated floors. Material can be loaded into the tunnel either using a vehicle or an automatic overhead system. The waste can be loaded to a depth of 3-4 meters, depending on its density and porosity, and is then left to compost. Temperature can be controlled through the rate of aeration and through spraying water into the tunnels. Some tunnels have static floors and some have walking floors, where the material is slowly moved through the tunnel. The residence time for the tunnels can vary between about 14 and 28 days, depending on the level of stabilisation required. It is possible to either, compost the waste in tunnels and then move it to windrows to stabilise, or to both compost and stabilise the waste in tunnels. In order to ensure that all of the waste reaches high enough temperatures to sterilise it often the waste is moved to a new tunnel half way through the process, in between the composting stage and the stabilisation stage.

Summary of Benefits/Disbenefits of composting techniques

A summary of the benefits, disbenefits and suitability of the four evaluated composting processes is provided in **Table 2.3** below.

Table 2.3: Benefits/Disbenefits of composting techniques

Composting Option	Benefits	Disbenefits	Suitability for OWTF2
Passive piles	• Simple and generally effective • Low labour and technology input requirements • Low capital and operation costs	• Vulnerable to climate changes • Difficulty in controlling VOC / odour emissions • Difficult to control vermin • cannot ensure that all material will reach a high enough temperature to sterilise compost • slow process (up to one year cycle) • Suitable only for relatively uniform materials • Low space efficiency • Can lead to anaerobic conditions leading to production of methane, and associated climate change impacts • Potential fire hazard	Not-suitable
Turned windrows	• Able to handle large volumes • Low capital investment • Rapid drying with high temperatures • Effective pathogen removal • Drier product, resulting in easier handling of materials • Good product stabilisation	• Low space efficiency • Additional labour required for turning and monitoring • Vulnerable to climate changes • Difficulty in controlling VOC / odour emissions • Difficult to control vermin	Not-suitable
Aerated static piles	• Able to handle large volumes • Relatively space-efficient • Effective pathogen removal • Effective odour control • Good product stabilisation	• Additional operation and maintenance costs and energy requirement for blowers and fans	Suitable
In-vessel systems	• Space efficient • Good control of composting process with confinement and automation • Effective in controlling odours • Uniform product • Effective pathogen removal • Protection from climate • Low visibility • Continuous process	• High capital costs • Additional operation and maintenance costs and energy requirement for blowers, fans and automation equipment	Suitable