COMPOSTING PROCESSING

TECHNOLOGIES

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SUMMARY

This is an abridged excerpt from a report produced for the Ontario Ministry of Environment in response to their request for an assessment of the state of organics in Ontario and perceived barriers/challenges to move organics recovery forward in the province. The report was produced by The Composting Council of Canada and its collaborators, MacViro and the Association of Municipal Recycling Coordinators. The findings and suggestions were put forward by the report's authors and do not represent any endorsement by the Ontario Ministry of Environment.

Composting, as defined for the purposes of this study, is the actively managed process of decomposition of organic residuals in the municipal solid waste stream. A range of composting systems is designed to manage this decomposition process to yield a high quality compost product without creating a public nuisance or negative environmental impact.

Composting is a biological process that is optimized when the starting carbon to nitrogen ratio is in the range of 30:1 and the moisture and oxygen levels and temperatures are closely managed and monitored. When processing household organics, it is of critical importance to have the right starting mix of feedstocks, and to manage moisture, oxygen and temperatures closely in order to minimize the risk of nuisance factors and environmental impacts.

This report presents ten composting methodologies that are being used in North America to manage the source separated household organics (SSO) fraction of the residential solid waste stream. Historically, windrow composting and static pile composting have been viewed as the most simplistic and least costly approaches to processing municipal organics. While that perception applies to centralized composting of leaf and yard waste, introducing the SSO fraction, especially for facilities servicing urban and suburban collection routes and thus have to be sited within a reasonable hauling distance, none of these methodologies can be defined as simplistic and least costly. Each has trade-offs in terms of overall costs, e.g., a windrow system may have less upfront investment in equipment and structures, but can have higher operating and management costs to address environmental impact and public nuisance factor considerations. Therefore, each methodology must be evaluated considering the following factors:

- Maximizing control of public health/nuisance factors;
- Optimizing throughput (to yield positive project economics and fulfill processing contract obligations); and
- Producing a high quality compost product.

This section describes and evaluates technologies and systems for the actual composting phases. Related equipment at composting facilities can include front end loader(s), grinder, mixer, screens and blower fans.

Windrows

General Description: Outdoor composting in piles that rely on mechanical aeration, typically with a compost windrow turner, to optimize the composting process. Windrow facilities with straddle turners (a turner which goes over the top of the pile) are limited in pile height by the height of the turner. Other turner technologies, e.g., elevating face, perform the turning function from the side and therefore pile height is less of a constraint. Generally speaking, however, to optimize the windrow composting process, pile height typically is limited to 3 to 4 metres.

SSO to be composted are either premixed prior to being formed into a windrow, or are layered (e.g., typically on a bed of ground yard trimmings, wood chips or sawdust) and then mixed with the turner. To control release of odours when the food scraps in the SSO are "fresh," some windrow facility managers create the windrows and then wait for a few days or a week before the first pile turning. In some cases, the windrows are covered with a layer of ground yard trimmings, which acts as a biofilter during this initial stage.

In a windrow, temperature control and oxygen levels are managed via mechanical agitation. Pile temperature and oxygen level need to be taken by a site operator with hand-held monitoring tools. Pile turning introduces oxygen, accelerates physical degradation of feedstocks and provides an opportunity to adjust the moisture content to the optimum level. Many windrow turners have a watering attachment, which enables moisture to be added to the pile while turning. Generally speaking, the total composting time can be managed by the aggressiveness of the turning regime. More frequent turning breaks particles down more quickly, and provides an opportunity to optimize composting conditions, thus accelerating the composting process. This enables a windrow composting facility to increase its annual throughput capacity.

The approximate processing cost of composting SSO in open windrows is $70/te (Halton Region Report, MacViro, 11/04).

Because SSO is typically composted with ground wood waste and/or leaf and yard waste as the bulking agent, the SSO can be an added feedstock to an existing yard trimmings windrow composting operation. There are a number of yard trimmings facilities in the U.S. that have added the preconsumer, vegetative waste stream (e.g., spoiled grocery store produce) to their accepted feedstocks. However, the regulations become more restrictive if a facility wants to process household organics, or postconsumer food waste. The state of California, for example, requires that SSO or postconsumer feedstocks be composted initially in some type of containment system[1] to eliminate direct contact with the pad surface (to control leachate) and avoid vector attraction. This requirement has made open-air windrow composting unacceptable in California for the initial phase of SSO composting. The curing phase of composting, however, takes place in outdoor windrows.

[1] Containment does not mean that a building enclosed system has to be installed. For example, Ag-Bags can be used to contain the material in the initial composting phase, before it is placed into outdoor windrows.

Enclosed Aerated Windrow

General Description: An aerated windrow is essentially a hybrid between a windrow and an aerated static pile. It uses both forced air (to more directly control oxygen levels and temperatures) and pile agitation, which accelerates the physical breakdown of composting materials and thus the composting process. Facilities using aerated windrows typically house them in a building, where the composting hall floor has aeration trenches covered by grates. Process air is directed to a biofilter outside of the building. Few, if any, facilities solely use aerated windrows by themselves to compost the SSO stream. Typically, aerated windrows are used after initial processing in rotary drums (typically three-day retention time in the drums) or with in-vessel containers.

Aerated Static Pile

General Description: Aerated static pile composting is comprised of forcing (positive) or pulling (negative) air through a trapezoidal compost pile. Agitation only occurs when piles are combined or moved to a different area for curing. To better manage odours, piles often are covered with a layer of finished compost or wood chips, which then are incorporated when the piles are moved. The aerated static pile composting method was developed in the early 1970s primarily for composting municipal sewage sludge. For biosolids, a bulking agent is needed to provide pile porosity to enhance the flow of air and control temperatures. Wood chips were determined to be the optimum bulking agent (although over the years, there has been some experimentation with shredded tires); these are recovered through screening and recycled back into the initial pile mix. One advantage of aerated static pile composting is the ability to capture the process air for odour treatment (typically through a biofilter). Outdoor aerated static pile operations need to use negative aeration (pulling air down through the pile) in order to direct it to an odour control system. Indoor aerated static piles can use positive aeration, with building air removed and treated through an odour control system.

It is rare that aerated static piles are used to compost materials that need to physically breakdown (as well as biologically). That is because, unlike windrows, static piles are not turned frequently. Therefore, aerated static piles still are primarily used today to compost biosolids or feedstocks of similar consistency and homogeneity. There are some facilities processing source separated and mixed solid waste that use aerated static piles for the second phase of composting but that is typically for the final curing, after particle degradation (or removal via screening) has occurred.

As noted, aerated static piles are rarely used in isolation to compost SSO. Instead, they are employed during the second phase of composting (curing) when a site wants the ability to capture and treat odourous air. The primary disadvantage of using this technology for SSO is that the lack of mechanical agitation, which slows down physical breakdown of materials.

Enclosed Aerated Static Pile (Non-Vessel)

General Description: When composting facilities first began using silage storage bags for composting, marketed as "pods," it was difficult to neatly classify this type of system. Essentially, this technology uses aerated static pile composting in a heavy-duty plastic (polyethylene) silage bag. Air is blown into the bags and exits through small ports on the sides of the bag. In its annual composting facility surveys, *BioCycle*, Journal of Composting & Organics Recycling (www.biocycle.net) started labeling this composting method "enclosed aerated static pile," to distinguish it from in-vessel composting, which takes place in rigid enclosures (e.g., metal containers, concrete bays). In the United States, a number of facilities composting source separated organics (primarily commercial and institutional but also SSO) use this bag technology because it provides containment at a lower capital cost than rigid vessels. The active composting phase typically is followed by windrow composting to accelerate breakdown of feedstocks (typically the ground leaf and yard waste fraction) that did not physically degrade during the period without mechanical agitation. The bags can be placed on a compacted surface (not paved) and still meet regulatory requirements to compost SSO. Materials are premixed and loaded into the bags using a mechanical ram or auger-like rotor. Typically, bags are installed on a slight slope so that leachate runs to one end and can be managed.

A more engineered enclosed aerated static pile composting system was introduced in Europe over a decade ago. The technology utilizes a patented membrane cover that is permeable to gaseous substances but retains odour emissions. Piles are built on a concrete pad with aeration trenches. An automatic winding device pulls the cover over the piles; the cover is sealed to the ground at the base of the piles, preventing air from escaping. Air is blown up through the piles. Odourous compounds, contained in condensation where the surface of the pile meets the membrane cover, are trapped and precipitate back into the pile, which essentially acts as a biofilter, degrading odour compounds. Once time, temperature and vector attraction reduction requirements are met, composting can be completed in open windrows. A handful of composting facilities processing (or permitted to process) SSO have started using the membrane cover technology. It appears to be effective at odour treatment and provides containment, thus meeting the approval of local air quality regulators and site neighbours.

The polyethylene pods come in 60 metres lengths but lose about 1.5 metres at each end when filled. The smallest pod is 1.5m in diameter. A full pod holds approximately 150 m^3 or 70 tonnes of feedstock. The largest pod is 3 metres in diameter and holds about 380 m^3 or 180 tonnes. Shorter pods can be created by cutting and clamping the bag with a sealing strip, which also is used to seal full-sized pods.

Enclosed Aerated Static Pile (Non-Vessel) Composting Equipment: The bag system requires the bags, aeration equipment, a bag filler and some equipment to premix feedstocks. The membrane cover system is a package that includes the membrane covers, winder, controls and aeration equipment. A concrete pad (with aeration trenches or plastic piping) is needed.

With both the plastic bags and the membrane cover; a building is not required, thus reducing initial capital costs. In some cases, facilities prefer to cure compost in a pole barn-type structure to keep materials dry and thus optimize end product screening. One advantage of the pods is that a facility can compost significant volumes of material without the capital costs of purchasing multiple in-vessel containers or building additional concrete bays. (Conversely, sites demanding smaller footprints may not be able to utilize this pile containment method.) While the capital costs for the membrane cover technology are higher than the pods, the system enables a facility to control odours, which is critically important, both from a public nuisance and a public perception standpoint. A key reason why local county health and air quality officials in Washington State approved this technology for SSO is because of its design to manage process emissions.

Modular In-Vessel Containers (Static)

General Description: Contained composting systems are modular; individual containers are added as volume increases. The number of units or modules determines the scale of operation. This category of in-vessel systems uses a static composting method, i.e., there is no mechanical agitation while material is in the container or tunnel. Instead, agitation is provided when material is unloaded. Fans supply oxygen and remove moisture and heat. In most cases, air is introduced at the base of the material and flows up through the composting mass into a headspace at the top. In other examples, air is pulled through the material. In either aeration mode (positive or negative), process air is treated through a biofilter, frequently housed in a separate container. Several commercial container systems are in use to process SSO. What varies among the commercial systems is the type of container, size and details such as the control devices, loading equipment and leachate management.

Some systems are modelled after, or made from, steel solid waste roll-off containers, which provide a durable enclosure that is modular and moveable. As containers are filled, they are connected to a central air delivery manifold. Materials are composted as a batch. In typical operations, containers are filled; after a period of time, e.g., 10 days to two weeks, containers are unloaded so that their contents can be mixed and the moisture content adjusted, if necessary. Some facilities use the tipper mechanism on a roll-off truck to unload the containers. Over the years, manufacturers of in-vessel containers have modified aeration systems, leachate management and insulation in order to optimize the composting process for year-round operation. The aeration and process control strategies for these units can be versatile and highly technical, involving computer controls (both on-site and remote), monitoring of several process parameters, variation in air flow rate and direction, and air recirculation. In typical installations, materials remain in the containers for approximately 3½ weeks, and then need to be further cured in windrows or aerated static piles.

Modular containers are located outside, thus eliminating the need for a building with odour control for the most active phase of composting. However, most composting sites using this technology have a building for both the curing phase, and to unload the containers (to avoid that point source of odours and be able to operate in all weather conditions). Therefore, there is still the need for capital investments in a structure and odour treatment. The batch composting process, with the ability to adjust the starting mix and reload the container, can be helpful in optimizing the composting process "mid-stream" (versus some technologies, such as agitated bays or enclosed aerated static piles, where that is impractical if not impossible). The downside is that more labour and equipment are involved. Some facilities are able to use the same truck used for roll-off container collection routes. Over 20 containers can be served by a single aeration and biofiltration system. Each additional container improves the economics by spreading out the fixed costs of the aeration and process control system, biofilter, mixer, container tipper and other materials handling equipment. While the containers can be used from start to finish for composting SSO, facilities typically only use them for the active phase, reserving the intense process control and air treatment for when composting feedstocks are most volatile. This reduces the number of total containers needed, and thus lowers initial capital costs. Like aerated static pile methods, using containers for SSO does not provide the mechanical agitation to physically break up particles. Therefore, to accelerate the overall composting time (and thus increase throughput), facilities use mechanical agitation during the final phases of composting.

Modular In-Vessel Tunnels (Static)

General Description: Tunnel composting systems are essentially aerated containers that have forced aeration through a floor plenum, internal air circulation and usually a biofilter. They are loaded from one end and operate in batch mode after the tunnel is fully loaded. Multiple tunnels can be used to attain a nearly continuous operation. Tunnel dimensions vary considerably. At the several installations using tunnels to process MSW and/or biosolids in North America, materials are loaded and unloaded using front-end loaders.

Tunnel Composting Equipment: Tunnels, aeration system, biofilter and loading/unloading equipment (typically a front-wheeled loader).

Modular in-vessel systems have the flexibility to do more than just compost SSO. As with the other static pile type systems, using static tunnels for SSO does not provide the mechanical agitation to physically break up particles. Therefore, to accelerate the overall composting time (and thus increase throughput), facilities use mechanical agitation during the final phases of composting. These systems also only serve to complete the initial breakdown of the material. The product from these tunnels is not a stable compost product; there is still the need for a curing stage, which typically is done in a separate windrow composting facility.

In-Vessel Bays (Mechanical Agitation)

General Description: Agitated beds compost materials in “beds” contained by long channels with concrete walls. A turning machine, travelling on top of the beds, agitates and moves the materials forward. Forced aeration is provided through the floor of the channel; the top of the channel is open. Therefore, an agitated bed is technically not a vessel, but falls into this category because it almost always (at least for residential organics composting) is enclosed in a building. Most systems are operated in the positive aeration mode (air blown up through the pile) to avoid leachate building up in the aeration manifolds, reducing the flow of air. To concentrate the process air to be treated for odours, some systems have plastic curtains around the perimeter of the bays (and in some cases, there is a drop ceiling to further contain odourous air). This reduces overall ammonia levels in the entire building, enabling operators to safely work around the perimeter of the bays (e.g., loading and unloading operations). It also helps to contain the moisture and ammonia being released from the composting materials, which contribute to corrosion of the building.

All agitated bays operate in a similar fashion. Feedstocks are mixed and loaded in the front end of the channel. Starting at the discharge end, the turner moves down the channel toward the front or loading end. With each pass, material is displaced a set distance toward the back of the channel until the materials are eventually discharged as compost that has met time and temperature requirements for pathogen and vector attraction reduction. Depending on the turner, material is shifted 2m to 4m with each turning. The length of the channel and the turning frequency determine the composting period in the channel (generally 10 to 28 days). Dimensions of individual channels vary among the commercial systems with depths ranging from 1 m to 2.4 m and widths of 1.9 m to 3.8 m. Channel lengths typically range from about 60 to 90 m. Most applications use multiple channels and a single turning machine. Larger facilities (expanded by adding more bays) may have two agitating units. There are some technologies that use a single, wide bed, e.g., 7.4 m to 12 m wide and 30 m long. An overhead bridge crane supports and moves the turner down the bed in strips.

Agitated Bay Composting Equipment: Proprietary equipment in an agitated bay system is typically the agitator and the aeration/overall system design. Vendors offer bays of various widths and heights; some are housed in fabricated metal structures while others are housed in fabric structures. All facilities processing SSO treat process air through a biofilter. Materials typically are premixed before being loaded in the bays; most cure material in a separate structure (open-sided or enclosed). At some installations, aeration is provided in the curing phase.

In-Vessel Vertical Silos

General Description: Vertical silos in use for composting municipal organics are passively-aerated, i.e., there is no forced aeration. Instead, the material is contained in vertical, wire-mesh “cages” that enable air to flow through. The cages can be tall (e.g., 3.7 m to 4.3 m high) and long but are usually only several feet wide. Therefore, the core of the composting mass is, at most, two feet from the air space that surrounds the cage.

Several vertical silo technologies were marketed in the 1980s for composting municipal biosolids. Unlike the cages just described, these are steel-fabricated vessels that are loaded on the top by conveyors; air is forced through the composting mass. One system, which is still marketed in North America, designed a patented “air-lance” technology, with rigid plastic aeration “tubes” running vertically within the silo. Most installations had two silos, one for active composting and the second for the curing phase. Material was transferred from one unit to the other via a conveyor.

Biosolids composting facilities using the vertical silo technologies were challenged by the difficulty in providing an even flow of air throughout the composting mass. Therefore, many of these operations were plagued with odour problems. Like the other static composting systems reviewed here, the lack of physical agitation could slow down physical degradation of the composting materials. Material being composted is pre-digested, thus it should be fairly uniform in particle size and somewhat degraded (thus making the lack of agitation a non-issue). The inability to contain and treat the process air (if the silos are located outside to take advantage of air flow) could be a challenge for sites using this technology when neighbours are in fairly close proximity.

Rotary Drums

General Description: Rotary drums (also called digesters) are included in this section because a number of the solid waste composting systems in North America utilize a drum as the first stage of composting. Rotary drums are not, in and of themselves, a composting technology. They must be used in tandem with another composting method. Rotary drums are popular because they serve several purposes: blending, size reduction without shredding, and screening. Over the three day retention time, the composting process is initiated, providing some degradation of feedstocks, particularly food waste. Air is fed into the drum to aerate the material; process air typically is treated through a biofilter. As material exits the drum, it passes through a screen, removing contaminants. Proponents of drums over mechanical shredding of composting feedstocks cite a better ability to sort contaminants, especially plastic, as it has not been reduced to small pieces that can keep passing through screening systems.

One important distinction between rotary drums and in-vessel containers is that the latter can be used for the entire composting process (active and curing phases), whereas the drums, realistically, can only be used for the initial step. Most facilities with in-vessel containers only use them for the first stage where maximizing process controls is critical; using containers for the entire composting process would be costly.

Rotary Drum Equipment: Essentially the drum stands alone, replacing grinders or shredders and mixing equipment at a composting facility. There are usually infeed and outfeed conveyors.

Anaerobic Digestion

General Description: Anaerobic digestion (AD) is the biological breakdown of organic materials in the absence of oxygen. In the process, biogas containing methane and carbon dioxide is produced. This biogas can be used as a fuel to generate energy. The material remaining after digestion is a partially stabilized organic material, which can then be aerobically cured and used as compost.

Anaerobic Digestion Equipment: Proprietary equipment with a pulping system to pulverize or machinate the infeed materials into a consistent size feedstock for the anaerobic digestion chamber or silo. Vendors offer systems of various throughput capacities, with abilities to directly inject liquids (e.g., manures, sludges, etc.). One and two stage anaerobic digestion systems are available, where the solids are pressed from the liquids and processed in a separate system. All facilities processing SSO treat process air through a biofilter. Materials typically are premixed before being loaded in the silos; all curing of materials are done in a separate structure (open-sided or enclosed). At some installations, aeration is provided in the curing phase.

Anaerobic digestion has a number of advantages, including:

- Energy Generation: The biogas produced in AD provides a fuel for the generation of electricity and/or heat, displacing the use of fossil fuels. AD can be a net producer of energy. This is in contrast to composting, which requires the consumption of energy to provide aeration for microbial activity.
- Environmental Benefits: Greenhouse gas emissions are reduced by the processing of waste by anaerobic digestion, both by the displacement of fossil fuel emissions and the capture of carbon in the waste, which would otherwise have been released to the atmosphere as CO_2 (composting) or CH_4 (landfilling).

The disadvantages of anaerobic digestion include the following:

- Cost: Anaerobic digestion is substantially more expensive than aerobic composting. Economies of scale can bring costs down for larger plant sizes, but the cost can be expected to be in a range that is comparable to incineration and advanced thermal treatment.
- Track Record of Technology: Although anaerobic digestion has had some success in Europe, the technology remains to be proven in North America. There have been facilities of demonstration scale and some attempts at large scale facilities. The success of AD is contingent on a number of factors including quality of feedstock, electricity prices, and end product markets; conditions in North America for these factors differ from those in Europe.
- Odour Concerns: Since anaerobic digestion deals with the biodegradable portion of the waste stream (the portion that rots), odours from an AD plant can be a concern. Although public perception of AD is generally positive, odour episodes from a working AD plant can turn local public opinion against the plant. A plant that is designed and operated to minimize odour releases should not have major odour problems, but it is an issue that should be considered in the planning and siting of a plant.

The first two disadvantages are quite significant. In spite of the advantages of AD, the fact that it is expensive and not yet fully proven in North America makes it a less realistic option than aerobic composting options.

Capital Cost Ranges

The capital cost ranges shown below are per throughput tonne assuming a minimum of 50,000 throughput tonnes per year.

- Windrowing: $40 - 60 per throughput tonne
- Enclosed Windrowing: $100 - $150 per throughout tonne
- In-vessel aerobic composting: $300-$500 per throughput tonne
- Anaerobic digestion: $500-$700 per throughput tonne