Compost Material Handling Options
Using the Intermodal Container Application
of the NaturTech Composting System

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Composting Theory – Agitation, Aeration and Inoculation

Nature does not "compost", meaning make piles. Nature mulches, meaning organic materials are left on the top of the soil as thin layers. It is humans that make piles, and once material that might otherwise be left in a layer is placed in a pile, the process, in a certain sense, is "un-natural". Humans must add soil organisms to effect decomposition in these "un-natural" piles, add water, and otherwise try to replicate the process of decay in the topsoil. Over time, humans have attempted various strategies to optimize, enhance, accelerate or otherwise control decomposition in pile.

Dating back to 1877, there are over 5000 US patents describing various composting methodologies, and invariably they all revolve around three principles, which are agitation, aeration, and inoculation. Nearly all describe some form of agitation and or aeration in various combinations. Less than a dozen of these patents describe a proprietary inoculant, and those that do are associated more with specific types of fermentation or odor treatment of some form. In the United States and Europe, few commercial composting technologies utilize cultured microbes or reagents, relying instead on naturally occurring organisms commonly found in topsoils throughout the world.

While many have tried to introduce or optimize certain microbial populations in the composting process, but research has shown that the same organisms that decompose organic matter in the soil are the ones responsible for decomposition in the soil. In fact, decomposition is increasingly being understood as a sequential process of over twenty microbial groups, with one group feeding off the remains of the previous group. Adding one group of organisms out of proper sequence is typically ineffective, and consequently compost system designers try to create conditions to let microbial sequencing occur at its own natural rate, resulting in a product we call "compost'. Studies have shown that recycling finished compost back into fresh material helps to optimize the rate of decomposition, seeding the old culture back into the fresh material like making yoghurt, baking bread with yeast, or brewing beer.

In simple terms, composting methodologies rely, to varying degrees, on two actions; agitation and aeration. The two are often mistaken for each other, as some operators claim that they "turn their pile" to provide aeration, while data shows that a windrow actually consumes its oxygen in as little as 30 minutes, making the aeration value of windrow-turning insignificant. The purpose of aeration in a windrow is actually to provide a short burst of aerobic heat to support heat loving anaerobic decomposition. The heat is retained by the insulating properties of the pile, and eventually the pile must be turned again to reheat, lest the anaerobes cool and stop decomposing.

A rotating tube digester may be described as a composting process that is 95% agitation and 5% aeration while an aerated static pile may be defined as 5% agitation and 95% aeration. But at only 24 to 72 hours retention and high capital cost, rotating tubes should be used only for initial conditioning, not composting. I have never seen a rotating tube hold temperatures over 55C for 72 hours, and material in process becomes contaminated due to commingling with fresh material. The microbial populations are not optimized in such systems and often have to work with other organisms that typically operate in a sequence, not simultaneously.

Since mixing and agitation is a more expensive proposition that supplying air with blowers, finding the "sweet spot" of minimal agitation and maximum aeration is the goal of the NaturTech Composting System. The NaturTech Composting System is a fully aerobic process and does not need "turning to generate heat" like non-aerated piles. Forced air instead provides oxygen that microbes use to produce heat which must be removed by air if the pile is not going to rise in temperature over 65C such that desired microbes die. Pause to think that most compost users have never had the pleasant experience of using a fully aerobic compost, as most windrow compost products are predominantly anaerobically digested.

Two key claims of Jim McNelly's composting patents, of which the NaturTech Composting System is an example, are the methodologies of aerated static piles in a container and secondly agitating, re-conditioning and or re-mixing the material outside the container after a week or so. NaturTech may be described as a system that is 75% aeration and 25% agitation. After the first seven days of static aeration, this one time agitation event assists in achieving the optimum rate of decomposition and a uniform finished compost product. The mix at seven days is an opportunity to add water, recover space lost in 30% volume reduction, and re-homogenize the decomposing mass enabling the following groups of microbes to become dominant.

Although it is often referred to as an "enclosed aerated static pile", the NaturTech remixing option differentiates containerized composting from static piles that have no turning or remixing stage. Conventional static piles are made with one-time use perforated plastic pipe and static piles are tedious to construct, requiring a 300mm wood chip base and a 300mm wood chip cap, or cover. Aerated static piles are associated with problems such as lack of homogeneity, channeling or short circuiting of air, odors, incomplete digestion, and lack of uniformity in the finished compost. Aerated static piles are often covered with fabric of some sort, a challenge to drape over the piles and remove. Snow removal is by hand over these fabric covers.

NaturTech's concept of "moving the compost to the mixer" instead of "moving the mixer through the compost" requires specialized equipment and material handling practices designed to keep costs low. At first look, some operators see a large number of containers and think that material-handling costs will be high. In actuality, however, NaturTech's containerized composting approach greatly reduces material handling requirements, providing some of the lowest operating costs of any modern composting system. Front end loaders move up to 4 tons per cycle with 225HP whereas a 20 or a 40 ton container can be moved with only 78 HP. This can result in up to a $6.00 per ton savings in fuel alone.

The main reason to agitate a second time in the batch mixer, however, is to add water. The first five days of composting are the most active, generating the most heat and requiring high volumes of air to keep temperatures low. Heat exchange with air has the effect of removing moisture, often to levels below 50%, which can inhibit the next 14 days of composting. Many forced aeration systems such as tunnels have been abandoned because the compost dries out too much to continue decomposition. Reintroducing moisture is nearly impossible in tunnel reactors, static piles, or containerized systems that do not use this patented NaturTech feature of external re-mixing. Even a theoretical auger routing its way through a composting batch from the top is not a true homogenization process. It may agitate, but it does not blend. Weighing the water using the scale on the conveyor and thoroughly homogenizing the mass a second time it is far more reliable water addition method than having a person standing on top of a windrow with a garden hose and a watch.

Compost Transfer

NaturTech uses a centralized tipping and filling system, sharing equipment to both dump and fill. Conventional composting relies on front-end loaders and dump trucks to move compost from the mixing area to the windrows (mix in the windrows is the old method) and again scoop by scoop from the windrows to the screening area. The typical dump truck load is approximately 20 cubic yards, or ten tons. The maximum payload for a truck to go on the road is around 22 tons. Container straddlers can move up to 50 tons. It is often the case that NaturTech systems often eliminate the need for a dump truck.

For the 25 ton and larger digesters, NaturTech uses heavy-duty intermodal handling equipment such as side-loaders or straddlers. It is in these larger systems that the NaturTech system achieves its best economies of scale as defined by throughput to total capital cost. These efficiencies are achieved using heavy duty tippers reducing the time required for a “cycle” of moving compost from the aeration grid to the tipper..

The great advantage of straddling cranes is that they can stack containers up to three high, Top-loader container handlers that operate like giant fork lifts are more practical in some circumstances, being capable of not just moving containers from the mixing area and back, but for stacking containers up to three high. They cost up to $750,000 new, although used units under $250,000 that can stack small containers two-high are often available. Their disadvantage is in the wide aisles required to turn and transport containers vs straddlers or side-loaders that can work with narrow aisles.

Transfer trailers come in three configurations, transfer trailers, tipper trailers, and the “side-loader” trailer. All three sysetms have multiple wheels capable of handling the weight of either 40’ 40 ton digesters or 45’ high cube 55-ton digesters, making each straddler a custom unit. Transfer and tipper trailers have a winch system that grabs the corners of the container, lifts it, then transports it to the tipping area. Straddlers require thirty-foot aisles for the large 45’ digesters and 15 foot aisles for the 20’ digesters. Transfer trailers can cost from $60,000 up to $350,000.

The tipper trailer is a transfer trailer that can also dump its load. It is equipped with “outriggers” like a backhoe capable of stabilizing the trailer and balancing it while compost is dumped out the rear at 55 degrees. This trailer can be taken to a surge bin with a stacking conveyor, or coupled with a hopper with a stacking conveyor. It can even dump on the ground, forming windrows. Tipper trailers can cost from $70,000 up to $150,000. Tipper trailers, however, are limited to 20’ digesters. Larger digesters require stationary tippers.

The “side-loader” trailer is a piece of equipment used for moving containers on-site at container handling terminals. It works by straddling a container lengthwise, reaching out, picking up a container by its side, then lifting and placing it on the trailer. It can pick up and set down containers either direction. A significant

advantage of the side-loader trailer is that it can also stack containers two-high, requiring only ten-foot aisles. This can be an advantage when placing a container onto a tipping platform; especially a side-tipper as the tipper can be elevated to begin with, reducing the cost of building the tipper. The side-loader trailer is the preferred transfer system for sites with limited available space. The side-loader system can cost from $140,000 up to $200,000.

The side-loader system, however, is not designed to handle the high weights of the larger digesters. The largest side-loader trailer every built can only handle a gross of 42 tons. The high cube digesters can weigh up to 60 tons fully loaded. The smaller 20' digesters are rated up to 30 tons. There is an option of using the larger containers filled only two thirds full, which gets closer to the capacity of the side-loader trailer than the 20' digesters, but running large digesters one third empty is very inefficient. Compared to oversize roll-off trucks costing $100,000, the cost of a truck $80,000, the trailer $150,000 and a tipper at $220,000 can be $350,000 more. This may be practical in sites that require optimum space efficiency of double stacking and narrow aisles.

The transfer, tipper, and swing-thru trailers all require a separate semi tractor, often with a heavy-duty rear axle that can cost over $100,000. Transfer trailers can be used to deliver containers full of compost to customers, setting a lockable, clean container on the site where it can be opened and unloaded using skid-steer loaders or wheelbarrows. When empty, the transfer trailer can return and pick up the empty container, perhaps delivering a second load of compost. This transfer trailer delivery system can avoid contamination and clean up problems associated with dump truck delivery systems.

The Intermodal systems can place one way or returnable containers onto train cars, where weight is not the concern it is for road travel. If there is a suitable tipper at the other end, or a mobile tipper is transported along with a trainload of containers of compost, the NaturTech system can achieve the lowest delivery costs imaginable, going hundreds, even thousands of miles to reach markets rather than tens of miles using front end loaders and dump trucks.

Mixing

One of the greatest causes of failure in windrow composting systems is the lack of homogeneity and uniformity in the initial composting mixture. Front-end loader layering and mixing with a windrow turner is imprecise and too dependent on operator judgment. Only a controlled batch-mixer with a scale or a continuous flow mixer with a high degree of process control using automated hopper feeders can provide uniform recipe management. It is generally accepted by most composting professionals that controlled initial mixing is very important for all composting operations, but it is absolutely indispensable to systems that rely on forced aeration and temperature feedback. The lack of porosity or a mismanaged carbon to nitrogen ratio can be disastrous to a composting system that relies on forced air for oxygen and temperature control. We will not sell a NaturTech composting system without a controlled mixing system available.

To make the mixing stage as efficient as possible, conveyors are used to transfer the relatively small mixer batches into the containers. At two to eight mixer batches per container, it is important to be efficient with the front-end loader to keep the "cycle time" of filling a container to a minimum. Avoiding jamming of the discharge system is essential, as augers or chain conveyors such as those used in agricultural mixing operations do not work as well with composting feedstocks with irregular sized ingredients and wood chips. The viscosity and bridging properties of raw compostable materials is also a challenge, requiring cleats or ribs on a belt conveyor.

Transfer from the Mixer to the Composting Container

There are numerous ways to fill a container from the mixer, but they all are variations on either the front-end loader or conveyor themes. The open-top NaturTech digesters allow for either conveyor belt or front-end loader feeding. If a conveyor is used, it should be versatile if the mixer is mobile, meaning capable of being moved with the mixer alongside stationary containers, filling them without moving the containers. The front-end loader system is very basic and effective, but still requires a small discharge conveyor at the mixer to take material from the mixer to a bunker where the loader can scoop it up. If the mixer is stationary, the conveyor should be able to reach the center of the digester. For small systems under 20 tons per day, an operator standing on a mobile ladder with a rake can level the crown formed by the conveyor. Moving the digester under a stationary conveyor can fill the container.

For most systems, the conveyor should have a diffusing secondary spreader-belt capable of evening the load across the top of the bin. Even larger systems should consider an additional shuttling, or telescoping, transfer conveyor that can fill a container without having to position an operator tying up the truck to move the container. NaturTech also offers a "dumpster-veyor" apparatus that gradually moves a container under the conveyor using a rail, trolley and cable winch system that can be integrated with level sensors for automated filling.

In all cases, the ability to divert raw compost from the mixer to a staging area for loading into the container with a front-end loader should be designed for contingencies and surge capacity. The largest systems are designed with multiple mixers that share transfer conveyors with reversing shuttle belts capable of filling two containers without stopping the mixes, thereby minimizing the cycle time of filling a container and placing it on the aeration grid.

Container Unloading

Once composting is finished, or it is time to re-mix or transfer to a windrow or curing bin, the bins must be unloaded. On small NaturTech systems with 40 cubic yard digesters, containers can be moved around the yard and dumped using conventional roll-off trucks. For the larger 80 and 110 cubic yard digesters and curing bins, unloading containers up to 60 tons is more of a challenge. No roll-off system currently made is designed to handle such large containers. Consequently, there are two options, stationary tippers and customized tipper-trailers.

Stationary tippers are fixed units that dump either to the end or sideways, depending on the site requirements. They cost anywhere from $50,000 to $300,000 depending on the length of the container, the angle of the dump (55 degrees minimum) weight of the load, and whether the semi-tractor is dumped with the container. There typically needs to be a discharging hopper and conveyor system placed in an appropriately sized dumping pit. Various surge bins capable of holding at least an entire container worth of material may be required to enable the truck to unload quickly. These surge bins are often of a "walking floor" design and can cost between $50,000 and $200,000.

From the discharge conveyor at the end of the surge bin or pit, a screening facility may be positioned, saving the need for an additional hopper-feeding system to couple with the screen. The discharge conveyor should also be able to move like a radial stacking conveyor that can be used to fill dump trucks for transfer off-site or to fill additional containers. Similar to the mixer system, a radial stacking conveyor should be able to load directly to a surge bin or stockpile area for processing at a later time.

On small operations, less than 60 tons per day, the same hopper feeder that is used at the mixer can be shared with the tipper. Some operations share the engine and hydrostatic power supply from the truck to power the mixer, screen, conveyors, and tipper. The mixer can be modified to roll up onto the truck or trailer and further used as a collection vehicle picking up feedstock from various sources. The US Navy facility added a "J" lifter to raise 60 and 90 gallon totes into the mixer hopper, diffusing it throughout the bed by briefly turning on the augers. The Mississippi Topsoils facility uses its mixer to collect thickened biosolids from underneath the discharge of a centrifuge, recording the weight, and transferring the solids to the composting area where bulking materials are added.

Stationary tippers can be used to automate the process of supplying bulking materials such as wood chips, shavings, and inoculant into the mixer. If difficult-to-handle materials such as biosolids are loaded into the mixer using a front-end loader, weigh feed belts or belts controlled by the load cell scale on the mixer can be programmed to add the appropriate weights of easier-to-handle supplemental ingredients. A container hopper and conveyor system to feed the mixers can reduce labor, indoor storage space, and front-end loader requirements. In one design, a 900-ton per day facility could be operated with a single front-end loader. The tippers are re-loaded with full containers of bulking materials when necessary, again using containers for handling bulking materials, often located outside the building. This is especially advantageous when screening compost and re-mixing, as a dumping, stockpiling, and re-loading step is eliminated.

Trailer tippers are desirable for moving raw compost to curing areas if curing is taking place in windrows. The tipper trailer can dump a partial load, walk forward, and dump again, leaving a nearly perfect windrow. Containerized composting is not just an advantage in reducing building requirements; it is an advantage in reducing material handling and on-site transfer costs. Careful selection of the transfer, tipping, mixing, and discharging equipment, especially if a sloped building configuration is available to enable gravity to assist in material transfer, can save many dollars per ton in operations efficiency.