United States
Environmental Protection
Agency

Biosolids Technology Fact Sheet

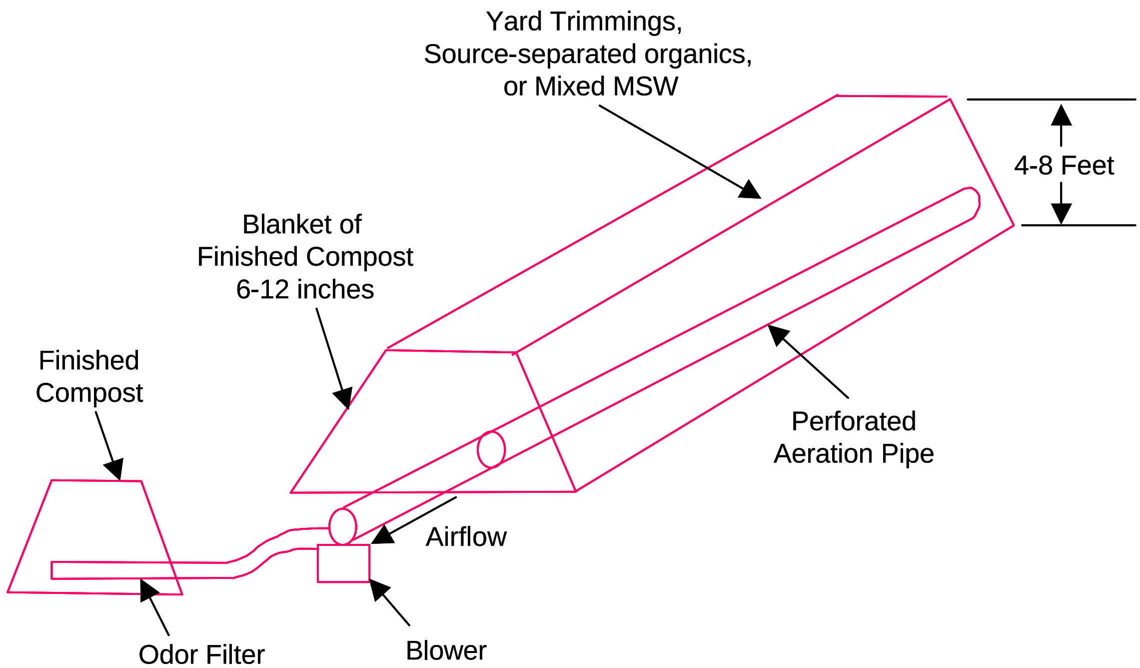
Use of Composting for Biosolids Management

DESCRIPTION

Composting is one of several methods for treating biosolids to create a marketable end product that is easy to handle, store, and use. The end product is usually a Class A, humus-like material without detectable levels of pathogens that can be applied as a soil conditioner and fertilizer to gardens, food and feed crops, and rangelands. This compost provides large quantities of organic matter and nutrients (such as nitrogen and potassium) to the soil, improves soil texture, and elevates soil cation exchange capacity (an indication of the soil's ability to hold nutrients), all characteristics of a good organic fertilizer. Biosolids compost is safe to use and generally has a high degree of acceptability by the public. Thus, it competes well with other bulk and bagged products available to homeowners, landscapers, farmers, and ranchers.

Three methods of composting wastewater residuals into biosolids are common. Each method involves mixing dewatered wastewater solids with a bulking agent to provide carbon and increase porosity. The resulting mixture is piled or placed in a vessel where microbial activity causes the temperature of the mixture to rise during the "active composting" period. The specific temperatures that must be achieved and maintained for successful composting vary based on the method and use of the end product. After active composting, the material is cured and distributed. The three commonly employed composting methods are described in the following paragraphs. A fourth method (static pile) is not recommended for composting wastewater solids based on a lack of operational control.

Aerated Static Pile - Dewatered cake is mechanically mixed with a bulking agent and stacked into long piles over a bed of pipes through which air is transferred to the composting material. After active composting, as the pile is starting to cool down, the material is moved into a curing pile.



Source: Hickman, 1999.

FIGURE 1 SCHEMATIC OF A STATIC-PILE FORCED-AIR COMPOSTING PROCESS

The bulking agent is often reused in this composting method and may be screened before or after curing so that it can be reused.

Windrow - Dewatered wastewater solids are mixed with bulking agent and piled in long rows. Because there is no piping to supply air to the piles, they are mechanically turned to increase the amount of oxygen. This periodic mixing is essential to move outer surfaces of material inward so they are subjected to the higher temperatures deeper in the pile. A number of turning devices are available, including: (1) drums and belts powered by agricultural equipment and pushed or pulled through the composting pile; and (2) self-propelled models that straddle the composting pile. As with aerated static pile composting, the material is moved into curing piles after active composting. Several rows may be laced into a larger pile for curing. Figure 2 shows a typical windrow operation.

Source: Parsons, 2002.

FIGURE 2 WINDROW OPERATIONS ARE TURNED TO PROVIDE ADEQUATE AERATION FOR ACTIVE COMPOSTING

In-Vessel - A mixture of dewatered wastewater solids and bulking agent is fed into a silo, tunnel, channel, or vessel. Augers, conveyors, rams, or other devices are used to aerate, mix, and move the product through the vessel to the discharge point. Air is generally blown into the mixture. After active composting, the finished product is usually stored in a pile for additional curing prior to distribution. A typical composting vessel is shown in Figure 3. This technology is discussed in greater detail in the fact sheet entitled *In-Vessel Composting of Biosolids* (EPA 832-F-00-061).

Source: Parsons, 2002.

FIGURE 3 TYPICAL COMPOSTING VESSEL

All three composting methods require the use of bulking agents, but the type of agent varies. Wood chips, saw dust, and shredded tires are commonly used, but many other materials are suitable. The U.S Composting Council lists the following materials as suitable for use as bulking agents:

- Agricultural by-products, such as manure and bedding from various animals, animal mortalities, and crop residues.
- Yard trimmings, including grass clippings, leaves, weeds, stumps, twigs, tree prunings, Christmas trees, and other vegetative matter from land clearing activities.
- Food by-products, including damaged fruits and vegetables, coffee grounds, peanut hulls, egg shells, and fish residues.
- Industrial by-products from wood processing, forestry, brewery and pharmaceutical operations. Paper goods,

paper mill residues, and biodegradable packaging materials are also used.

- Municipal solid waste.

If municipal solid waste is used in compost, it is put through a mechanical separation process prior to its use to remove non-biodegradable items such as glass, plastics and certain paper goods (USCC, 2000).

The length of time biosolids are composted at a specific temperature is important in determining the eventual use of the compost end product. 40 CFR Part 503, *Standards for the Use and Disposal of Sewage Sludge* (Part 503) defines time and temperature requirements for both Class A and Class B products (Table 1). The production of a Class B product is not always economically justified since the product cannot be used without restrictions and the additional expense to reach Class A requirements can be marginal.

TABLE 1 PART 503 TIME AND TEMPERATURE REQUIREMENTS FOR BIOSOLIDS COMPOSTING

Product	Regulatory Requirements
Class A	**Aerated static pile or in-vessel**: 55 C for at least 3 days **Windrow**: 55 C for at least 15 days with 5 turns
Class B	40 C or higher for five days during which temperature exceed 55 C for at least four hours

Source: 40 CFR Part 503.

If the compost process conforms with the time and temperature requirements to produce a Class A product and the maximum pollutant levels of Part 503 are met, the material is considered "Exceptional Quality" (EQ) biosolids. If used in accordance with sound agronomic and horticultural practices, an EQ biosolids product can be sold in bags or bulk and can be used in household gardens without additional regulatory controls. Class A and EQ biosolids typically have greater marketing success than Class B biosolids. Control of industrial waste streams to wastewater treatment plants (through pretreatment programs) greatly reduces the presence of metals in pre-processed wastewater residuals, enabling compost to meet the stringent EQ standards of Part 503.

If the compost produced is Class B, it can be used at agronomic sites with no public contact, with additional site restrictions. Class A biosolids can be used in home gardens with public contact and no site restrictions. Consistent and predictable product quality is a key factor affecting the marketability of compost (U.S. EPA, 1994). Successful marketing depends on a consistent product quality.

Stability is an important characteristic of a good quality compost. Stability is defined as the level of biological activity in the compost and is measured as oxygen uptake or carbon dioxide production. Oxygen uptake rates of 50 to 80 mg/L are indicative of a stable product with minimal potential for self-heating, malodor generation, or regrowth of pathogen populations. Stability is also indicated by temperature decline, ammonia concentrations, chemical oxygen demand (COD), number of insect eggs, change in odor, and change in redox potential (Haug, 1993).

Stable compost consumes little nitrogen and oxygen and generates little carbon dioxide. Unstable compost consumes nitrogen and oxygen and generates heat, carbon dioxide, and water vapor. Therefore, when unstable compost is applied to soil, it removes nitrogen from the soil, causing a nitrogen deficiency that can be detrimental to plant growth and survival. In addition, if not aerated and stored properly, unstable compost can emit nuisance odors (Epstein, 1998, Garcia, 1991).

APPLICABILITY

The physical characteristics of most biosolids allow for their successful composting. However, many characteristics (including moisture content, volatile solids content, carbon content, nitrogen content, and bulk density) will impact design decisions for the composting method. Both digested and raw solids can be composted, but some degree of digestion (or similar stabilization) is desirable to reduce the potential for generation of foul odors from the composting operation. This is particularly important for aerated static pile and windrow operations. Carbon and nitrogen content of the wastewater solids must be balanced against that of the bulking agent to achieve a suitable carbon to nitrogen ratio of between 25 and 35 parts carbon to one part nitrogen.

Site characteristics make composting more suitable for some wastewater treatment plants than others. An adequate buffer zone from neighboring residents is desirable to reduce the potential for nuisance complaints. In urban and suburban settings, in-vessel technology may be more suitable than other composting technologies because the in-vessel method allows for containment and treatment of air to remove odors before release. The requirement for a relatively small amount of land also increases the applicability of in-vessel composting in these settings.

Another important consideration before selecting the technology to be used for composting is the availability of adequate and suitable manpower. Composting is typically labor-intensive for the following reasons:

- Bulking agents must be added.
- Turning, monitoring, or process control is necessary.
- Feed and finished material(s) must be moved with mechanical equipment.
- Storage piles must be maintained for curing and distribution.
- Bulking agents recovery adds another step.

Finally, proximity to the markets for the resulting compost is desirable, although the usefulness of the final product in home gardening and commercial operations generally makes the material marketable in urban as well as rural areas. This is especially true for good quality material that does not emit foul odors.

ADVANTAGES AND DISADVANTAGES

Biosolids composting has grown in popularity for the following reasons (WEF, 1995):

- Lack of availability of landfill space for solids disposal.
- Composting economics are more favorable when landfill tipping fees escalate.
- Emphasis on beneficial reuse at federal, state, and local levels.
- Ease of storage, handling, and use of composted product.
- Addition of biosolids compost to soil increases the soil's phosphorus, potassium, nitrogen, and organic carbon content.

Composted biosolids can also be used in various land applications. Compost mixed with appropriate additives creates a material useful in wetland and mine land restoration. The high organic matter content and low nitrogen content common in compost provides a strong organic substrate that mimics wetland soils, prevents overloading of nitrogen, and adsorbs ammonium to prevent transport to adjacent surface waters (Peot, 1998). Compost amended strip-mine spoils produce a sustainable cover of appropriate grasses, in contrast to inorganic-only amendments which seldom provide such a good or sustainable cover (Sopper, 1993).

Compost-enriched soil can also help suppress diseases and ward off pests. These beneficial uses of compost can help growers save money, reduce use of pesticides, and conserve natural resources. Compost also plays a role in bioremediation of hazardous sites and pollution prevention. Compost has proven effective in degrading or altering many types of contaminants, such as wood-preservatives, solvents, heavy metals, pesticides, petroleum products, and explosives. Some municipalities are using compost to filter stormwater runoff before it is discharged to remove hazardous chemicals picked up when stormwater flows over surfaces such as roads, parking lots, and lawns. Additional uses for compost include soil mulch for erosion control, silviculture crop establishment, and sod production media (U.S. EPA, 1997a).

Limitations of biosolids composting may include:

- Odor production at the composting site.
- Survival and presence of primary pathogens in the product.
- Dispersion of secondary pathogens such as *Aspergillus fumigatus*, particulate matter, other airborne allergens.
- Lack of consistency in product quality with reference to metals, stability, and maturity.

Odors from a composting operation can be a nuisance and a potential irritant. Offensive odors from composting sites are the primary source of public opposition to composting and have led to the closing of several otherwise well-operated composting facilities. Although research shows that biosolids odors may not pose a health threat, odors from processing facilities have decreased public support for biosolids recycling programs (Toffey, 1999). Many experts in the field of biosolids recycling believe that biosolids generating and processing facilities have an ethical responsibility to control odors and protect nearby residents from exposure to malodor.

Composting odors are caused by ammonia, amine, sulfur-based compounds, fatty acids, aromatics, and hydrocarbons (such as terpenes) from the wood products used as bulking agents (Walker, 1992). A properly designed composting plant, such as the one shown in Figure 4, operated at a high positive redox potential (highly aerobic) will reduce, but not necessarily eliminate, odors and odor causing compounds during the first 10 to 14 days of the process (Epstein, 1998). Control of odors is addressed in further detail in the fact sheet entitled Odor Management in Biosolids Management (EPA 832-F-00-067).

In addition to odors, other bioaerosols, such as pathogens, endotoxins, and various volatile organic compounds, must also be controlled. Biofilters are often used to control odors, but the biofilters themselves can give off bioaerosols.

Pathogens, such as bacteria, viruses, and parasites (helminth and protozoa), are present in untreated wastewater residuals. These organisms can potentially invade a normal, healthy human being and produce illness or debilitation. Composting reduces bacterial and viral pathogens to non-detectable levels if the temperature of the compost is maintained at greater than 55 C for 15 days or more. Additionally, it has been demonstrated that viruses and helminth ova do not regrow after thermal inactivation (Hay, 1996).

Regrowth of *Salmonella* sp. in composted biosolids is a concern, although research shows that salmonellae reach a quick peak during regrowth, then die off. Composting is not a sterilization process and a properly composted product maintains an active population of beneficial microorganisms that compete against the pathogenic members. Under some conditions, explosive regrowth of pathogenic microorganisms is possible. A stabilized product with strict control

Source: Parsons, 2002.

FIGURE 4 ODOR CONTROL EQUIPMENT CAN BE A SUBSTANTIAL PART OF CAPITAL INVESTMENT

of post-composting handling and addition of amendments coupled with four to six weeks of storage will mitigate *Salmonella* regrowth (Hay, 1996).

Compost workers may be exposed to a common fungus known as *Aspergillus fumigatus*, endotoxins, or other allergens. *A. fumigatus* is common in decaying organic matter and soil. Inhalation of its airborne spores causes skin rashes and burning eyes. While healthy individuals may not be affected, immunocompromised individuals may be at risk. The spores of *A. fumigatus* are ubiquitous and the low risk of exposure is not a significant health concern. However, spore counts at composting facilities are high, and the risk of operators and persons handling composted biosolids being exposed to these spores is also high (Epstein, 1998). Inhalation of spores, particulates, and other matter can be reduced or prevented by:

- Wearing masks and other protective devices.
- Equipping front end loaders with filters or air conditioners.
- Thoroughly ventilating composting halls.
- Installing biofilters or other odor scrubbing systems in composting halls (Epstein 1998).

Organic dust (such as pollen) is another nuisance that must be controlled at composting operations. These contaminants are primarily a concern to workers at the composting facilities and are generally not present in quantities that would cause reactions in most individuals that are not exposed outside of the facilities.

Environmental Impact

Potential environmental impacts may result from both composting operations and use of the compost product.

Composting Process

Dust and airborne particles from a composting operation may affect air quality. The impact to adjacent areas may need to be mitigated and permitted.

To protect area ecology and water quality, run-off from application sites must be controlled. The potential nitrogen and phosphorus rich run-off (or leachate) can cause algal growth in surface water and render groundwater unfit for human consumption.

Land Application of Compost Products

Excess nitrogen is detrimental to soil, plants, and water, so care must be taken when choosing application sites, selecting plant/crop types, and calculating the agronomic rate for biosolids land application. It should be noted that the most plant-available form of nitrogen in biosolids (ammonium ion (NH_4^+)) is converted to nitrate (NO_3^-) by the composting process. Improper use of biosolids can result in the contamination of water resources with leached nitrogen, because nitrate is more mobile than ammonium, and is taken up less easily by plants. However, applying compost in accordance with the Part 503 Regulations poses little risk to the environment or public health (Fermante, 1997). In fact, the use of compost can have a positive impact on the environment in addition to the soil improving characteristics previously discussed. Reduced dependence on inorganic fertilizers can significantly decrease nitrate contamination of ground and surface waters often associated with use of inorganic fertilizers.

PERFORMANCE

Composting is a viable, beneficial option in biosolids management. It is a proven method for pathogen reduction and results in a valuable product. According to a 1998 survey in *Biocycle, The Journal of Composting and Recycling,* 274 biosolids composting facilities were operating in the United States (Goldstein, 1999). Nearly 50 additional facilities were in various stages of planning, design, and construction. A large number of these facilities (over 40 percent) use the aerated static pile composting method.

Since 1984, EPA has encouraged the beneficial use of wastewater residuals through formal policy statements. The implementation of Part 503 enhanced the acceptance of biosolids as a resource by standardizing metal and pathogen concentrations. Moreover, Part 503 officially identifies composting as a method to control pathogens and reduce vector attraction.

Discussions of the specific performance factors of the three primary composting methods are provided below.

Aerated static pile systems are adaptable and flexible to bulking agents and production rates. Aerated static pile is mechanically simple, thus with lower maintenance than other cost method. Conversely, this configuration can be labor intensive and may produce nuisance odors and dust. Cover, negative aeration, chemically scrubbing, or use of a well-maintained biofilter may be required to minimize off-site odor migration. The popularity of the aerated static pile method is based on the ease of design and operation and lower capital costs associated with facility construction. Selection of an appropriate method requires an assessment of the physical facility, process considerations, and operation and maintenance costs (WEF, 1995).

Windrow composting is adaptable, flexible and relatively mechanically simple. However, the windrow configuration requires a large area and can result in release of malodor, dust, and other airborne particles to the environment during natural processing, ventilation, and windrow turning.

In-vessel systems are less adaptable and flexible compared with aerated static pile and windrow systems. However, in-vessel composting requires a smaller area. Because the reactor is completely enclosed, the potential for odor and the need for controls is increased. Due to the greater complexity of in-vessel mechanical systems, trouble can be encountered meeting peak flows, breakdowns are more frequent, and repairs are more difficult and costly. Failure of aeration devices, under- designed aeration systems, or lack of a back-up aeration method may cause large quantities of product to become anaerobic, and therefore, unacceptable. Often the compost residence time in in-vessel composting systems is inadequate to produce a stable product, particularly where the depth of the composting mass is great, (e.g., more than 3 m [10 feet]) and mixing does not occur. In addition, bridging sometimes occurs within these systems. Finally, depending upon the configuration and direction of air flow, the worker environment can be very hostile. However, in-vessel composting requires a smaller area and generates relatively little dust outside the facility.

Table 2 compares the three methods and highlights key features of each.

COSTS

The capital costs of aerated static pile or windrow configuration may be lower than in-vessel composting configurations, but costs increase markedly when cover is required to control odors. More highly mechanized in-vessel systems are often more costly to construct, but tend to be less labor intensive. On the other hand, in-vessel systems tend to be less flexible in their ability to adapt to changing properties of biosolids and bulking agent feedstocks.

Capital costs of in-vessel systems range from $33,000 to $83,000 per dry metric ton ($30,000 to $75,000 per dry ton) per day processing capacity. A typical aerated static pile facility costs approximately $33,000 per dry metric ton ($30,000 per dry ton) per day of processing capacity (Harkness, 1994; U.S. EPA, 1989).

Typical operation and maintenance (O&M) costs for in-vessel systems range from $150 per dry ton per day to greater than $200 per dry ton per day. Aerated static pile O&M costs average $150 per dry ton per day (Harkness, 1994; U.S. EPA, 1989). Costs for windrow systems fall between the costs for in-vessel and aerated static pile. The selling price for compost ranges from $5 to $10 per cubic yard or $10 to $20 per ton. Some facilities allow landscapers and homeowners to pick up compost for little or no charge.

TABLE 2 COMPARISON OF COMPOSTING METHODS

Aerated Static Pile	Windrow	In-Vessel
Highly affected by weather (can be lessened by covering, but at increased cost)	Highly affected by weather (can be lessened by covering, but at increased cost)	Only slightly affected by weather
Extensive operating history both small and large scale	Proven technology on small scale	Relatively short operating history compared to other methods
Large volume of bulking agent required, leading to large volume of material to handle at each stage (including final distribution)	Large volume of bulking agent required, leading to large volume of material to handle at each stage (including final distribution)	High biosolids to bulking agent ratio so less volume of material to handle at each stage
Adaptable to changes in biosolids and bulking agent characteristics	Adaptable to changes in biosolids and bulking agent characteristics	Sensitive to changes in characteristics of biosolids and bulking agents
Wide-ranging capital cost	Low capital costs	High capital costs
Moderate labor requirements	Labor intensive	Not labor intensive
Large land area required	Large land area required	Small land area adequate
Large volumes of air to be treated for odor control	High potential for odor generation during turning; difficult to capture/contain air for treatment	Small volume of process air that is more easily captured for treatment
Moderately dependent on mechanical equipment	Minimally dependent on mechanical equipment	Highly dependent on mechanical equipment
Moderate energy requirement	Low energy requirements	Moderate energy requirement

Source: Parsons, 2002.

REFERENCES

Other Related Fact Sheets

In-Vessel Composting of Biosolids
EPA 832-F-00-061
September 2000

Odor Management in Biosolids Management
EPA 832-F-00-067
September 2000

Centrifuge Thickening and Dewatering
EPA 832-F-00-053
September 2000

Belt Filter Press
EPA 832-F-00-057
September 2000

Other EPA Fact Sheets can be found at the following web address:

http://www.epa.gov/owm/mtb/mtbfact.htm

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