Composting Toilet Systems

NATIONAL SMALL FLOWS CLEARINGHOUSE

Fact Sheet

Project funded by the U.S. Environmental Protection Agency under Assistance Agreement No. CX824652

Introduction

Originally commercialized in Sweden, composting toilets have been an established technology for more than 30 years, and perhaps longer in site-built forms. As they require little to no water, composting toilet systems can provide a solution to sanitation and environmental problems in unsewered, rural, and suburban areas and in both developed and underdeveloped countries.

A composting (or biological) toilet system contains and processes excrement, toilet paper, carbon additive, and, sometimes, food wastes. Unlike a septic system, a composting toilet system relies on unsaturated conditions where aerobic bacteria break down wastes, just as they do in a yard waste composter. If sized and maintained properly, a composting toilet breaks down waste to 10 to 30% of its original volume. The resulting soil-like material, called “humus,” legally must be either buried or removed by a licensed septage hauler in accordance with state and local regulations.

Public health professionals are beginning to recognize the need for environmentally sound human waste treatment and recycling methods. The composting toilet is a nonwater-carriage system that is well-suited for (but is not limited to) remote areas where water is scarce, or areas with low percolation, high water tables, shallow soil, or rough terrain. Because composting toilets eliminate the need for flush toilets, this significantly reduces water use and allows for the recycling of valuable plant nutrients.

Although there are many different composting toilet designs that continue to evolve, the basic concept of composting remains the same.

Process Description

The primary objective of composting toilet systems is to contain, immobilize, or destroy pathogens, thereby reducing the risk of human infection to acceptable levels without contaminating the environment or negatively affecting the life of its inhabitants. This should be accomplished in a manner that is consistent with good sanitation (minimizing the availability of excrement to disease vectors, such as flies, and minimizing human contact with unprocessed excrement), thus producing an inoffensive and reasonably dry end-product that can be handled with minimum risk.

A composting toilet is a well-ventilated container that provides the optimum environment for unsaturated, but moist, human excrement for biological and physical decomposition under sanitary, controlled aerobic conditions. Some are large units that require a basement for installation. Others are small self-contained appliances that sit on the floor in the bathroom. In the composting process, organic matter is transformed by naturally occurring bacteria and fungi that break down the excrement into an oxidized, humus-like

continued—

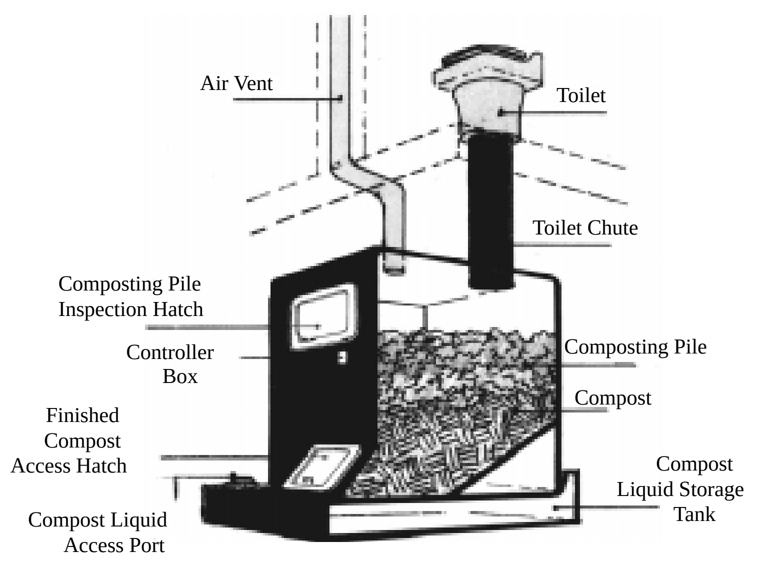

Figure 1: Composting Toilet

Adapted from: Clivus Multrum, Inc. (1994) with permission

This fact sheet was developed by Clement Solomon, Peter Casey, Colleen Mackne, and Andrew Lake.

WWFSOM28

ETI
Environmental Technology Initiative

end-product. These organisms thrive by aeration, without the need for water or chemicals. Various process controls manage environmental factors—air, heat, moisture—to optimize the process.

The main process variations are continuous or batch composting. Continuous composters (including such brands as CTS, Clivus Multrum, Phoenix, Biolet, SunMar, etc.) are single chambers where excrement is added to the top, and the end-product is removed from the bottom. Batch composters (including Carousel, Vera, and nearly all of the site-built composters worldwide) are actually two or more composters that are filled and then allowed to cure without the continuous addition of new potentially pathogen-contaminated excrement. Alternating concrete double-bins are the most common batch system, although several systems use polyethylene 55-gallon drums that contain the process.

The main components of a composting toilet (see Figure 1) are:

- a composting reactor connected to a dry or micro-flush toilet(s);
- a screened air inlet and an exhaust system (often fan-forced) to remove odors and heat, carbon dioxide, water vapor, and the by-products of aerobic decomposition;
- a mechanism to provide the necessary ventilation to support the aerobic organisms in the composter;
- a means of draining and managing excess liquid and leachate (optional);
- process controls to optimize and facilitate management of the processes; and
- an access door for removal of the end-product.

The composting unit must be constructed to separate the solid fraction from the liquid fraction and produce a stable, humus material with less than 200 MPN per gram of fecal coliform. Once the leachate has been drained or evaporated out of the unit, the moist, unsaturated solids are decomposed by aerobic organisms using molecular oxygen. Bulking agents can be added to provide spaces for aeration and microbial colonization.

The compost chamber in some composting toilets is solar or electrically heated to provide and maintain optimum temperature requirements for year-round usage.

Advantages and Disadvantages

Some advantages and disadvantages of composting toilet systems are listed below:

Advantages

- Composting toilet systems do not require water for flushing, and thus, reduce domestic water consumption.
- These systems reduce the quantity and strength of wastewater to be disposed of onsite.
- They are especially suited for new construction at remote sites where conventional onsite systems are not feasible.
- Composting toilet systems have low power consumption.
- Self-contained systems eliminate the need for transportation of wastes for treatment/disposal.
- Composting human waste and burying it around tree roots and nonedible plants keeps organic wastes productively cycling in the environment.
- Composting toilet systems can accept kitchen wastes, thus reducing household garbage.
- In many states, installing a composting toilet system allows the property owner to install a reduced-size leachfield, minimizing costs and disruption of landscapes.
- Composting toilet systems divert nutrient- and pathogen-containing effluent from soil, surface water, and groundwater.

Disadvantages

- Maintenance of composting toilet systems requires more responsibility and commitment by users and owners than conventional wastewater systems.
- Removing the finished end-product is an unpleasant job if the composting toilet system is not properly installed or maintained.
- Composting toilet systems must be used in conjunction with a graywater system in most circumstances.
- Smaller units may have limited capacity for accepting peak loads.
- Improper maintenance makes cleaning difficult and may lead to health hazards and odor problems.
- Using an inadequately treated end-product as a soil amendment may have possible health consequences.
- There may be aesthetic issues because the excrement in some systems may be in sight.
- Too much liquid residual (leachate) in the composter can disrupt the process if it is not drained and properly managed.
- Most composting toilet systems require a power source.
- Improperly installed or maintained systems can produce odors and unprocessed material.

Performance

There are several factors that affect the rate of composting. Discussed below are the predominant factors:

- *Microorganisms:* The microbiology is dominated by the presence of a mixed population of bacteria and fungi. The presence of these microorganisms is directly related to the environmental conditions in the compost material.
- *Temperature:* As the microorganisms grow, heat is generated by the energy released during aerobic microbial respiration. The temperature of the compost is significant from a public health perspective because of the need for destruction of pathogens. Temperatures typically never become high enough to rapidly destroy pathogens, so time and optimum environmental factors are more significant.
- *Moisture:* Moisture enables microorganisms to hydrolize complex organic compounds into simpler compounds before they are metabolized. The moisture should be maintained within the range of 40 to 70%, with the optimum being about 60%.
- *pH:* In composting toilet systems, pH is not typically a concern to the owner/operator, although the pH will initially drop as organic acids are formed. Other biochemical processes buffer the final end-product, bringing it to a neutral level. In general, the optimum pH is between 6.5 and 7.5.
- *Carbon to nitrogen ratio (C/N):* For complete utilization of the nitrogen in urine, an adequate amount of carbon (about 30

continued—

parts of carbon for each part of nitrogen) is required. However, as most urine drains to the bottom of the composter and is removed, this is less of a problem than is usually reported in literature.
- *Aeration:* Maintaining an aerobic environment in the composting chamber is the most important factor for the growth of microorganisms, reducing high moisture content, and minimizing nitrogen loss through ammonia volatilization. Aeration can be improved by mechanical mixing or by adding wood chips or sawdust to the composting material.
- *Management:* As with all wastewater treatment systems, management is critical to the efficiency of the system.

The two main parameters in the composting process that account for the destruction of pathogens are:
- *Antibiosis:* Microbial and other higher order aerobic organisms develop in the compost pile during the decomposition process, resulting in the synthesis of substances that are toxic to most pathogens.
- *Time:* When exposed to an unfavorable environment for an extended period of time, most pathogenic microorganisms will not survive. However, caution is essential when using the compost end-product and liquid residual in case some pathogens survive. Table 1 gives typical pathogen survival times at 20 to 30° C in various environments.

Table 1: Typical Pathogen Survival Times at 20 to 30°C in Various Environments

Pathogen	*Survival Time, Days* *Fresh Water and Wastewater*	*Crops*	*Soil*
Bacteria			
Fecal coliforms [b]	<60 but usually <30	<30 but usually <15	<120 but usually <50
Salmonella (spp.) [b]	<60 but usually <30	<30 but usually <15	<120 but usually <50
Shigella [b]	<30 but usually <10	<10 but usually <5	<120 but usually <50
Vibrio cholerae [c]	<30 but usually <10	<5 but usually <2	<120 but usually <50
Protozoa			
E. histolytica cysts	<30 but usually <15	<10 but usually <2	<20 but usually <10
Helminths			
A. lumbricoides eggs	Many months	<60 but usually <30	<Many months
Viruses [b]			
Enteroviruses [a]	<120 but usually <50	<60 but usually <15	<100 but usually <20

[a] Includes polio, echo, and coxsackie viruses.
[b] In seawater, viral survival is less and bacterial survival is very much less than in fresh water.
[c] *V. cholerae* survival in aqueous environments is a subject of current uncertainty.

Adapted from: Crites and Tchobanoglous (1998) with permission from The McGraw-Hill Companies

The standard governing minimum materials, design, construction, and performance of composting toilet systems is the American National Standard/NSF International Standard ANSI/NSF 41-1998: *Non-Liquid Saturated Treatment Systems*.

Application

Composting toilet systems can be used almost anywhere a flush toilet can be used. They are typically used for seasonal homes, homes in remote areas that cannot use flush toilets, or recreation areas, etc. Application advantages for composting toilet systems are listed below:
- It is more cost-effective to treat wastes onsite than it is to build and maintain a central sewer system to which wastes will need to be transported.
- Water is not wasted as a transport medium to flush toilets.
- Nutrients (nitrogen and phosphorus) are kept in tight biological cycles without causing problems to receiving waters.
- There have been many reports of successful use of waterless (composting, incinerator, chemical, and privy) toilets. Listed below are some examples in Maine and Colorado:

Replacement of Existing Disposal Systems

A family of four had a failing wastewater disposal system in their urban home. They lived on a small lot with insufficient land area to construct a disposal system for their water use. A waterless toilet was installed in conjunction with a 35% smaller disposal system to handle the remaining graywater.

Rejuvenation of an Existing Disposal System

A disposal system in a residential neighborhood had a history of surface breakouts due to overloading. The load was reduced when a waterless toilet was installed along with water conservation devices on plumbing fixtures.

Remodeling

A waterless toilet was installed in a basement near a family room because it was more practical than installing plumbing and a pump to lift the waste to a septic tank.

Waterless, Solar Toilets in Colorado Park

The Colorado Health Board was faced with the task of providing adequate toilets to the outlying portions of a 18,000-acre recreation area. The options considered were running a sewer and water line or installing chemical toilets and vault latrines. However, these options added to the problem with continual maintenance requirements, high chemical costs, expensive excavations and pump-outs, and the potential to pollute groundwater. Faced with this dilemma, the Colorado Health Board installed composting toilets to decompose wastes without water, chemicals, pollution, or odor.

The compost produced from the decomposed waste was similar to topsoil and reduced considerably in volume. Directly below the toilet chute was a large tank in which organic material such as lawn clippings, paper, and leaves was placed. The waste decomposed slowly along the tank floor by the natural bacteria present in the waste material. A fan powered by a small photovoltaic cell on the roof of each brick and concrete restroom was installed to draw out all vapors produced in the tank. Both the men's and the women's stalls were accommodated by a tank unit each to handle up to 40,000 uses per year, thus providing much-needed toilet facilities in outlying areas.

Operation and Maintenance

Handling raw waste has historically been a problem from a management standpoint. Removing vault- or pit-type waste has

continued—

led to accidental spills and is always a difficult task. This is why managers appreciate the concept of composting human waste.

Management considerations for composting toilets include gathering information on how much maintenance is needed annually, administration and operation, quality control and assurance, record-keeping, and training.

In general, operation and maintenance (O&M) for composting toilet systems does not require trained technicians or treatment plant operators. However, regular O&M is of the utmost importance since any system depends on responsible administration. In cold climates, all composting toilet systems should be heated to levels specified by the manufacturer or designer.

Composting toilet systems may require organic bulking agents to be added, such as grass clippings, leaves, sawdust, or finely chopped straw. They assist composting by providing a source of carbon for the bacteria, as well as keeping the pile porous for proper air distribution. If the facility is used every day, it is recommended to add bulking material at least every other day. Periodic mixing or raking is suggested for single-chamber continuous systems.

The other required maintenance step is removing the finished end-product (anywhere from every 3 months for a cottage system to every 2 years for a large central system). If proper composting has taken place, the end-product should be inoffensive and safe to handle. Adequate precautions should be taken while handling the humus material. All waste materials should be disposed of in accordance with the state and local regulations.

Cost

The cost of a composting toilet system depends on the manufacturer and their type of design. Although the principle of waste treatment is the same, there are design variations in the containment of the waste, aeration, and other features of the system. The main factors that determine costs are the cost of the equipment, the building foundation, electrical work, and installation labor.

For a year-round home of two adults and two children, the cost for a composting toilet system could range anywhere between $1,200 and $6,000, depending on the system. Cottage systems designed for seasonal use range from $700 to $1,500. Large-capacity systems for public facility use can cost as much as $20,000 and more. However, site-built systems, such as cinder-block double-vault systems, are as expensive as their materials and construction labor costs. A septic tank and soil absorption or subsurface irrigation system to manage graywater will usually be required.

References

Clivus Multrum, Inc. 1994. “When nature calls... it calls Clivus®.” Clivus Multrum, Inc. Lawrence, Massachusetts.

Cook, B. 1981. “Field Evaluation of Compost Toilets.” Individual Onsite Wastewater Systems: Proceedings of the Seventh National Conference. pp. 83–98.

Crites, R. and G. Tchobanoglous. 1998. *Small and Decentralized Wastewater Management Systems.* The McGraw-Hill Companies. New York, New York.

Del Porto, D. A. and C. J. Steinfeld. 1998. *The Composting Toilet Book.* Chelsea Green Publishing, Inc. Whiteriver Junction, Vermont.

Felton, D. (editor). 1981. “State-Of-The Art Assessment of Compost Toilets and Greywater Treatment Systems.” The Winthrop Rockefeller Foundation. Little Rock, Arkansas.

Guttormsen, D. 1979. “Evaluation of Compost Toilets—A Field and Laboratory Update.” Individual Onsite Wastewater Systems: Proceedings of the Sixth National Conference. Ann Arbor Science Publishers, Inc. Ann Arbor Michigan.

Hoxie, D. C. and W. W. Hinckley. 1977. “Factors Affecting Acceptance of Waterless Toilets—The Maine Experience.” Individual Onsite Wastewater Systems: Proceedings of the Fourth National Conference. National Sanitation Foundation (NSF).

Jacobson, A. R. January 1982. “Waterless, Solar Toilets for Colorado Park.” *Public Works.* vol. 113. no. 1. p. 85.

Rockefeller, A. 1980. “Separated Treatment: Composting Toilets and Greywater.” Conference Proceedings. pp.104–118. Environmental Policy Institute and Clean Water Fund. Cambridge, Massachusetts.

Scholze, R. J. 1984. “Appropriate Technology for Army Waste Management: Applications for Remote Sites and Mobilization.” DAEN-ZCF Technical Note No. 84-2. Department of the Army, Office of the Chief of Engineers. Washington, D.C.

Scholze, R. J. September 1985. “Innovation in Remote Site Waste Treatment.” *BioCycle.* pp. 37–38.

Scholze, R. J.; J. E. Alleman; S. R. Struss; and E. D. Smith. December 1986. “Technology for Waste Treatment at Remote Army Sites.” USA-CERL Technical Report N-86/20. USA-CERL. Champaign, Illinois.

Seabloom, R. W. and J. Engeset. March 1 & 2, 1978. “An Appraisal of Composting Toilets.” Proceedings of the Second Northwest On-Site Wastewater Disposal Short Course. University of Washington. Seattle, Washington.

Smith, E. D.; C. P. C. Poon; S. R. Struss; J. T. Bandy; and R. J. Scholze. April 1984. “Appropriate Technology for Treating Wastewater at Remote Sites on Army Installations: Preliminary Findings.” USA-CERL Technical Report N-160. USA-CERL. Champaign, Illinois.

The mention of trade names or commercial products does not constitute endorsement or recommendation for use by the National Small Flows Clearinghouse (NSFC) or U.S. EPA.

For more information on composting toilet systems or a list of other fact sheets, contact the NSFC at West Virginia University, P.O. Box 6064, Morgantown, WV 26506-6064. Phone: (800) 624-8301 or (304) 293-4191. Fax: (304) 293-3161. World Wide Web site: http://www.nsfc.wvu.edu.

The NSFC provides free and low-cost informational services and products to help homeowners and small communities address their wastewater needs. Also, information about manufacturers, consultants, regulations, and facilities can be obtained from the NSFC’s databases.