
CASE STUDY: COMPOSTING TOILET SYSTEMS IN THE UNITED STATES

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SYSTEM MANUFACTURERS STUDIED:

- CLIVUS MULTRUM
- SUN-MAR
- COMPOSTING TOILET SYSTEMS, INC.
- SANCOR INDUSTRIES, LTD.
- ADVANCED COMPOSTING SYSTEMS, LLC.

FACILITIES STUDIED:

- UNIVERSITY OF BRITISH COLUMBIA, C.K. CHOI BUILDING
Vancouver, Canada
- CALVIN COLLEGE, BUNKER INTREPRETIVE CENTER Grand Rapids,
MI
- BRONX ZOO, ECO-BATHROOM Bronx, NY
- SOUTHFACE ECO-OFFICE Atlanta, GA
- MOUNTAIN EQUIPMENT CO-OP Winnipeg, Canada
- BAR-T MOUNTAINSIDE CAMP Urbana, MD
- STREETWATER CREEK VISITOR CENTER Atlanta, GA
- THE ECHOES HARRISON RIVER RETREAT British Columbia, Canada
- RED PINE WILDNERNESS LODGE Ontario, Canada
- RAYSTOWN FIELD STATION, SHUSTER HALL Huntingdon, PA
- ORGAN PIPE CACTUS NATIONAL MONUMENT Ajo, AZ
- COTTONWOOD CAMPGROUND Coconino, AZ
- WOLF EDUCATION AND RESEARCH CENTER Winchester, ID

PUBLICATIONS:

- Hill, Geoffrey B. & Baldwin, Susan A. (2012). Vermicomposting toilets, an alternative to latrine style microbial composting toilets, prove far superior in mass reduction, pathogen destruction, compost quality, and operational cost. *Waste Management*, 32, 1811-1820.

PURPOSE & SCOPE:

This case study was compiled to use as reference and comparison of existing composting toilet systems and manufacturers in the United States and Canada. Information was collected through phone conversations, online information and email correspondence. Confidential information is denoted in *underlined italics* and should be handled sensitively and considered for internal use only as requested by the supplier of the information.

The purpose of this work is to establish the advantages and disadvantages of existing decentralized compost toilet systems. This information can be used to compare with and support the centralized Thermopile Project composting system.

EXECUTIVE SUMMARY:

Five composting toilet manufacturers were reviewed for this case study, four of which were explored further by studying facilities that have implemented their systems and technologies. In total, thirteen facilities were studied comprising of commercial office buildings, state park visitor centers, colleges, universities, retail stores, lodges, campgrounds, and a zoo. Seven facilities have implemented Clivus Multrum systems, three have implemented Composting Toilet Systems, Inc., two have implemented Sun-Mar systems and one has implemented Advanced Composting Systems LLC technologies. Of the thirteen facilities, only two have utilized both the liquid and solid compost, two have utilized only the solid compost and one has utilized only the liquid compost. Several system users have discovered that the temperatures necessary for pathogen reduction are never achieved, thus causing fecal coliform levels to be above the allotted amount for land application. Facilities that do not utilize their compost due to the lack of pathogen reduction must contract local sanitation companies for removal of their compost for further treatment or are connected directly to the sewer. Very few of these systems perform as they are advertised and require additional disposal costs including connection to local sewers, manual removal, or in some cases, system replacement.

These cases reinforce the point made by Geoff Hill and Susan Baldwin that composting both urine and fecal material together on a decentralized scale is not effective at achieving necessary temperatures for pathogen reduction. Although Hill and Baldwin encourage source separating vermicomposting toilets, they conclude that decentralized mixed latrine composting toilets are not sufficient and this process would need to be done in a centralized location in order to achieve temperatures necessary for pathogen reduction. Hill and Baldwin's article *Vermicomposting toilets, an alternative to latrine style microbial composting toilets, prove far superior in mass reduction, pathogen destruction, compost quality and operational cost* is reviewed in the Publications section of this case study.

SYSTEM MANUFACTURERS

CLIVUS MULTRUM, INC.

www.clivusmultrum.com

Clivus Multrum originated in Sweden in 1939 and is possibly the largest and oldest manufacturer in the world of composting toilet systems. They market their systems as being able to eliminate all harmful pathogens from human waste where the finished solid compost can be used in home gardens and the liquid compost, mixed with water can be used to irrigate flowers, trees and grass. Clivus Multrum offers waterless, micro-flush and vacuum flush systems appropriate for a wide variety of uses. Clivus Multrum also provides graywater recycling design and the systems themselves.

The majority of facilities studied in this Case Study implement Clivus Multrum systems.

SUN-MAR

www.sun-mar.com

Sun-Mar composting toilets have been a family-owned business in North America since 1971 and were the first to introduce the self-contained composting unit that could compost and evaporate liquid all in one chamber in the bathroom. Sun-Mar is also responsible for the first composting toilet with a rotating drum. Sun-Mar offers 22 composting toilet models, many of which utilize their international patented rotating drum technology.

Sun-Mar offers non-electric (NE) models, central flush systems, central dry systems and self contained systems.

Two facilities were studied in this Case Study that implement Sun-Mar systems.

COMPOSTING TOILET SYSTEMS, INC.

www.comtoilet.com

Composting Toilet Systems, Inc. (CTS) has been in business manufacturing and distributing composting toilet systems since 1978 in North America. CTS is a distributor of Sun-Mar composting toilets as well as CTS brand toilets.

Several facilities that utilize CTS systems were studied in this Case Study.

ADVANCED COMPOSTING SYSTEMS, LLC.

www.compostingtoilet.com

Advanced Composting Systems, LLC. (ACS) is an American manufacturer of the Phoenix Composting Toilet System. This company advertises that finished compost can classify under the EPA standards as a Class B Biosolid and used for land application as defined under 40 CFR 503, Standards for the Use and Disposal of Sewage Sludge. The contact at ACS believes that the County Health Departments are the normal regulating agencies for composted human waste, but their tests show that fecal coliform levels are completely eliminated or extremely low.

One facility using ACS systems were studied in this Case Study. Others were contacted but not reached for further information.

[Contact at ACS: Ried, Sales Associate, ried@compostingtoilet.com, (406) 862-3854]

SANCOR INDUSTRIES, LTD.

www.sancor.ca

Sancor Industries, Ltd. has manufactured and marketed advanced composting systems in Northern America under the brands Santerra Green and Envirolet. Santerra Green composting toilets are sold at retailers such as Sears, Lowe's, Home Hardware etc.. Envirolet is a line that is sold factory direct as an alternative to septic tank systems in homes, cottages or cabins.

Both Santerra Green and Envirolet offer waterless, low flush and vacuum flush systems and have lifetime replacement warranties, and a 5-year internal part warranty. All systems have the option of installing a one or two-tank composting unit. In a one-tank composting unit, a drain can either divert liquid waste to a leach field or for a family of four or less, can drain the leachate directly into the soil. In a two-tank composting unit, the liquid waste is diverted to another tank where it is evaporated and composted separately.

Specific facilities using these systems were not covered in this case study as their products are marketed mostly for residential use. Various phone conversations divulged further information not listed on their website.

FACILITIES STUDIED

CLIVUS MULTRUM, INC.

C.K. CHOI BUILDING
UNIVERSITY OF BRITISH COLUMBIA
Vancouver, Canada

10 M28 Waterless Composting Toilets & 3 Unsealed Urinals

The C.K. Choi Building is a LEED certified building on the campus of UBC. It houses the Institute for Asian Research. Originally, the C.K. Choi building was designed so that liquid waste would filter through the solid compost and accumulate in a graywater trench where it was then used for irrigation. Finished compost was intended for land application to the gardens around the building.

In 2011, Geoff Hill, a research student at the university, discovered that the fecal coliform levels in both the solid and liquid finished compost were much higher than expected, and much higher than provincial regulations would allow. Upon consultation with an expert that was contracted by the University to oversee a graywater and blackwater treatment facility on campus, the University was convinced they were not complying with provincial regulations. This discovery halted the application and use of both the solid and liquid compost from the composting toilet systems. Liquid waste is now being drained to the local sewer and solid waste will be deposited in a sanitary landfill when necessary.

It has been reported that temperatures have never reached the necessary temperatures required for pathogen destruction and it has been discussed to replace these systems altogether. Another issue with the composting system in the C.K. Choi building was odor. According to a Vancouver Coastal Health (VCH) -Environmental Health Department Officer, this problem was solved by keeping windows open year round. This officer also mentioned that leachate in the basement was becoming a problem but did not intervene.

According to UBC, the same odor problem VCH mentioned is only a concern when someone opens the composting drawer and breaks the vacuum seal which pulls the odor from the restroom in the building down to the composting units in the basement.

UBC comprises such a large surface area of Vancouver it is considered its own entity in many applications. The City of Vancouver does not have jurisdiction over the campus. Vancouver Coastal Health Department does oversee UBC activities. UBC is also subject to compliance under the Provincial Building Codes.

The Ministry of Health, which Vancouver Coastal Health is a subdivision of, does not have regulations pertaining to composting toilets. They are more concerned with graywater, which in British Columbia, is the same as blackwater. The building codes that redefine the difference between black and graywater are currently evolving. The Ministry of the Environment is currently exploring and evolving their regulations on how to dispose of composted human waste as well.

BUNKER INTERPRETIVE CENTER
CALVIN COLLEGE
Grand Rapids, MI

3 Foam-Flush Composting Toilets

The Bunker Interpretive Center is a study-center at Calvin College and an education center for the general public. This building is LEED certified, and located in Grand Rapids, Michigan, the LEED certified capital of the world. When installing the composting toilet systems, regulations required that a backup drainage field be constructed onsite in the case of excess of liquid waste. The drainage field was installed in 2004 along with the composting toilet system and has not needed to be used yet. The Center also has a graywater recycling system.

The City of Grand Rapids and Kent County have strict regulations pertaining to the disposal of composted human waste. Land application is not approved so liquid compost is pumped out by a local sewage company and in the 8 years the system has been in use, the solid compost has not needed to be removed.

Because of the remote location of the Center, usage is inconsistent which the management has attributed to the higher than preferred E. coli levels in the compost. The liquid compost accumulates quickly and removal is required often. Other than these issues, no other system problems have been reported.

ECO-BATHROOM
BRONX ZOO
Bronx, NY

14 toilets and 4 foam flushing urinals

The Bronx Zoo has turned a normal bathroom experience, into an interactive learning one. With signs regarding water usage, waste management and conservation, users learn the advantages of using the foam flush, composting toilets. The composters sit in a 12-foot basement and contain a starting material which consists of red worms, fungi and bacteria.

The Eco-Bathroom was built seven years ago, and according to Clivus Multrum, solid compost will not be ready to be removed until eight to ten years after installation. The liquid waste is held in a 100-gallon tank, which is removed by a local cesspool company once a month. In the warmer months, the liquid waste is removed twice a month because of odor. The biggest problem the Eco-Bathroom has is odor, which they attribute to the liquid waste, not the solid.

In addition to the composting toilet systems, the graywater is recycled and used to irrigate the Graywater Garden, located adjacent to the Eco-Bathroom. Irrigation is performed using sub-soil drip lines.

The only major problem reported due to a storm that caused the basement housing the composters to flood. This made the composters float off the floor and move, therefore breaking all the pipes and causing quite a mess. This was remedied by bolting the units to the floor in the basement.

Clivus Multrum maintains the systems while maintenance at the Bronx Zoo is responsible for cleaning only. All system malfunctions and issues are handled by Clivus Multrum.

SOUTHFACE ECO OFFICE
SOUTHFACE INC.
Atlanta, GA

Foam-Flush Composting Toilets

Southface's Eco Office is part of a non-profit organization that promotes comfortable energy, resource and water efficient homes, workplaces and communities in the South East. The Eco Office is a demonstration and learning tool for other projects to use and explore efficient technologies.

The toilets are flushed with collected rainwater and the composters are equipped with sawdust and redworms that have been successfully maintained and running for 3 to 4 years. Solid compost has not yet needed to be emptied from the composters and liquid compost is collected and used for irrigation through sub-soil drip lines onsite. In speaking with the [REDACTED] Manager, [REDACTED], the building may have benefited from smaller composting units and waterless systems. A hollow shaft fixture would have been preferable, according to [REDACTED], but were sold on the fixture design and the "self-cleaning" marketing of the foam-flush. He mentioned also that the "self-cleaning" advertisement is not completely true, and to keep a toilet brush handy and sometimes extra water is needed. [REDACTED] believes that the system is too large for the limited amount of users and therefore has slowed the finished compost production. According to [REDACTED], the composters are more so composters of the woodchips and sawdust that they truck in, not

the human waste. The composting unit has a separator for finished compost and raw material.

The liquid compost tea is held in a holding tank and is valued as a great plant fertilizer. The tea however, contains the bubbles and soapy residue from the foam-flushing mechanism, which is an alkaline solution. Irrigation using this alkali tea has killed and prevented growth of some plants. The Eco Office is looking into agricultural methods to return to a more neutral soil pH.

When the building was first designed, the engineers thought that they could run fresh air through a heat exchange using the hot, humid air from the composting room for building air circulation. They quickly found this to cause a strong odor through their air vents and quickly disconnected. The rooftop patio and garden was also subject to odor, but was quickly resolved by extending the vent pipe by 20 feet.

This project was one of the first of its kind in Atlanta and required special permitting to be approved. The county health department caught wind of a tour guide advertising that compost tea was being used for spray irrigation, they inspected the site, and eventually left them alone after realizing this was not the case.

Overall, the Eco Office is very happy with their system, they love it and works great. They are very interested in our project implementing composting systems in California and would love to be updated on our progress.

MOUNTAIN EQUIPMENT CO-OP Winnipeg, Canada

Waterless Composting Toilet

Mountain Equipment Co-Op is a climbing and outdoors equipment retailer in Winnipeg, Canada. Their store contains a waterless composting toilet that was originally intended to provide liquid fertilizer to their rooftop garden. This fertilizing system is no longer being practiced according to the store manager. The only problems that have been reported have been attributed to neglect in maintenance due to the high turnover rate of employees (as common in a retail environment). Currently, the system seems to be getting back to a healthy state after failing.

BAR-T MOUNTAINSIDE CAMP Urbana, MD

Several waterless composting toilets

The Bar-T Mountainside Camp is a summer camp and before and after school care facility. There are composting toilets dispersed throughout the camp for use by staff and campers.

The liquid compost is used in gardens and landscape around the area through spray irrigation out the back of a tractor. The solid compost has not yet needed to be removed from the composters. The camp has not encountered any major problems with the composting toilet systems and is relatively low maintenance. In addition to the composting toilet systems, the camp has a graywater recycling system that uses sub-soil irrigation to water wildflower fields in the camp.

The county regulates the composting and graywater systems and inspects the site on a quarterly basis. While installing the composting toilet systems, the camp was required to install the necessary equipment should they choose to switch over to a conventional septic system in the future.

Overall, the camp is very happy with the system.

SWEETWATER CREEK VISITOR CENTER
SWEETWATER CREEK STATE PARK
Lithia Springs, GA

Foam-Flush composting toilets

The Sweetwater Creek Visitor Center is located in the Sweetwater Creek State Park in Georgia. The composting toilet systems have been installed for 6 years. Their system collects rainwater and uses it for flushing.

Their compost tea system is very unique. The liquid compost drains through the bottom of the composters and is mixed with graywater underground in a 1000-gallon septic tank where suspended particles are removed from the solution. Liquid waste then moves on to a 1000-gallon dosing tank and then pumped into the sub-soil irrigation system. Diilting the compost tea with graywater allows for more frequent irrigation using the compost tea. In the 6 years the systems have been in place, solid compost has yet to be removed.

Only minor problems have arisen so far, and Clivus Multrum has flown people down to Georgia to fix these problems. These problems were not specified. The worst problem so far was a fruit fly infestation that must have laid eggs in the composter because a swarm of fruit flies flew out of the system and clogged the air vents going to the outside of the building. They cleaned the air vents and the problem was resolved.

To the best of their knowledge, the compost tea/graywater irrigation practice is not regulated. The Water & Sewer Authority was involved in the regulations required for installation of the system.

SUN-MAR

THE ECHOES
HARRISON RIVER RETREAT
Harrison Hot Springs, British Columbia, Canada

The Echos is a bed and breakfast type retreat with 12 cabins. Family owned and operated, they have installed at least 12 waterless composting toilets in the cabins and are very happy with the systems.

This B&B is a seasonal retreat, where peak months are March through November. During the off season, which coincides with the colder months, the composters are left unmaintained and the contents in the composters turn white and appears as though they are growing mold. Once a year, the solid compost is removed and dumped into the septic system. The liquid waste is constantly drained into the septic system through a drain at the bottom of each composter. I spoke with [REDACTED] the Echos and [REDACTED] expressed her concern in using the finished solid compost on her lawn because she is concerned that her dogs would dig in it and is not confident that it was safe for them.

The Echos is unsure of any regulatory matters pertaining to their practices, they were told when they installed the systems that the regulations were changing but would not be put in place until long after their system would be up and running. They have not returned to the issue since installation.

One thing the owner mentioned that she strongly dislikes about the system is that once a year when the weather gets hot, fly larvae ends up in the compost and flies hatch and take over the cabins. Sun-Mar told her to spray a chemical in the composting units to kill larvae, but then consequently, disrupts the composting environment and adds toxic chemicals to the mix.

[After some further research, I found that several Sun-Mar systems have experienced this problem. One site attributed it to the design that diverts most liquid waste away from solid waste, Sun-mar claims it is caused when operators add topsoil to the composting unit, which often contains fly larvae.]

RED PINE WILDERNESS LODGE
Ontario, Canada

The Red Pine Wilderness Lodge is bed and breakfast-type lodge equipped with at least 12 non-electric low flush toilets.

Overall, the Lodge is very happy with the systems and the only problems they have encountered have been due to too much volume or too much water being added to the toilets. Solid waste is used on the lawn at the Lodge and liquid compost is mostly evaporated, unless there is excess in which case it is diverted to a leach field.

Regulations have not been an issue; owner James Bowen said that the Sun-Mar system itself is regulated and the standards have been achieved for NSF Standard 41 so the land application regulations are not necessary.

COMPOSTING TOILET SYSTEMS, INC.

SHUSTER HALL
RAYSTOWN FIELD CENTER
Huntingdon, PA

3 CTS waterless toilets

Shuster Hall is a classroom, dining room and multipurpose room at the Raystown Field Station, which is part of Juniata College. The building is LEED certified and is used for residential immersion students in the Fall and Spring.

The composting toilet system was installed in 2004 and the solid compost has yet to require removal. The liquid compost is diverted to an on-site wastewater treatment facility, which was required by the building codes. The site intended to use composting toilet systems in the dormitory buildings on site, but composting toilets did not suffice as “proper waste treatment” as defined by local codes. In order to use the composting toilets, the wastewater treatment facility would have to be larger and the digesters to be constantly fed to keep activated, an expense the facility was unwilling to adopt. Other composting toilet systems in the area have been known to spread their finished compost on land in the forests that surround the area, and is the intended use for the finished solid compost from Shuster Hall.

The only problems Dr. [REDACTED], the Field Center Director, expressed was odor, which was easily resolved. Apparently, at first the system came with a sump pump accompanied by a side float, which would sometimes not activate. This was fixed by replacing the side float with a vertical float. Occasionally, when the power goes out and the venting fans stop, odor that is normally sucked away from the bathroom is trapped in the bathroom, causing an unpleasant odor. Dr. [REDACTED] also mentioned that occasionally when there is higher than normal usage, extra maintenance is required.

Overall, Dr. [REDACTED] said that the Center is very happy with the system and is maintained by students.

ORGAN PIPE CACTUS NATIONAL MONUMENT
ARIZONA NATIONAL PARK
Ajo, Az

2 CTS waterless toilets

The Organ Pipe Cactus National Monument is an International Biosphere Reserve where many endangered plants and animals take refuge. The extreme desert temperatures have shown to be problematic to the composting toilet systems.

The location and seasonality of this composting toilet system has created a non-ideal composting environment, as believed by the Chief of Maintenance of the National Monument. The toilet has been installed for approximately 20 years. The extreme heat of the desert causes the composting material to severely dry out in the summer when the system sees the most visitors. In the winter months, the system seems to function better, however visitation rates are extremely low and the inconsistency of visitors cause the composting system to struggle. Due to these factors, the material is not considered composted and is pumped out of the vaults twice a year.

The liquid and solid compost is held in the vault composters until pumped out by a sanitation company. Because neither liquid nor solid waste is applied to land, regulatory agencies are not involved in this system. Overall, according to [REDACTED], the system has never worked as they thought it would and are overall unhappy with the system. The most problematic issue being the weather patterns and visitation fluxes.

COTTONWOOD CAMPGROUND
GRAND CANYON NATIONAL PARK
Coconino, AZ

4 CTS waterless toilets

The Cottonwood Campground is located within the Grand Canyon State Park. Waterless composting toilets are located in very remote areas throughout the park. The systems are currently outdated and severely needing replacement. Proposals have been submitted to replace the systems with Advanced Composting Systems' Phoenix model.

Maintenance of these units require someone to hike, sometimes 20 miles per day, for servicing. Mules and helicopters are used to remove compost and garbage while delivering toilet paper and enzymes. The [REDACTED], said that they struggle quite a bit with users throwing trash into the units, which cause pockets of sewage. Overall, the compost is said to be pretty good, and is mixed with soil prior to land application. [REDACTED] claims that they are very effective units and have operated without problems during the extreme temperature flux and use in the Grand Canyon,

which is inconsistent with the information obtained from the previous study of the system at the Arizona National Park, Organ Pipe Cactus Monument.

ADVANCED COMPOSTING SYSTEMS

WOLF EDUCATION AND RESEARCH CENTER
Winchester, ID

Two waterless composting toilets with manually rotating drum and liquid catch basin with liquid compost recycling system.

The Wolf Education and Research Center is dedicated to public education and preservation of the population and habitats of grey wolves in Idaho. The composting toilet systems were built in 1996 by Advanced Composting Systems, Inc. The installed models were one of the first prototypes built by ACS, and are not technically the Phoenix System but very closely resembles it. Every couple days, operators must manually turn the drums to aerate the pile. A catch basin is located below the drum, which collects liquid that is then pumped back up and sprayed on top of the solid waste to maintain moisture levels in the composting drum.

The bathrooms are run off solar power and rainwater is collected for cleaning. In the last 15 years, the drums have needed to be emptied twice, where they gave the solid compost to a local hay farmer. The regulations in Idaho allow for land application of compost for non-human consuming crops. A small leach field was built for overflow of liquid waste should the catch basins reach their capacity.

Overall, the Research Center is very happy with the systems and have had very few problems. Every 3-4 years they have come across a glitch but the customer service at ACS has been phenomenal. They highly recommend ACS and their systems.

PUBLICATIONS

Hill, Geoffrey B. & Baldwin, Susan A. (2012). Vermicomposting toilets, an alternative to latrine style microbial composting toilets, prove far superior in mass reduction, pathogen destruction, compost quality, and operational cost. *Waste Management*, 32, 1811-1820.

*[*Geoff Hill is the Research Student at University of British Columbia who discovered the high levels of fecal coliform in finished compost from the C.K. Choi buildings composting units.]*

Summary:

Geoff Hill and Susan Baldwin contacted agencies operating public composting toilets in Western Canada, Pacific Northwest USA and Western Europe. They collected end-product samples for analysis from both Mixed Latrine Microbial Composting toilets (MLMC) and Source Separating Vermicomposting Toilets (SSVC). The results were compared and found that SSVC systems are superior over MLMC systems.

Hill and Baldwin found that Operating and Maintenance costs were significantly lower for SSVC systems compared to MLMC systems. Pathogen reduction was not achieved in MLMC systems and were unable to find any literature on the systems that stated otherwise. Vermicomposting techniques in the SSVC systems proved to digest pathogens and achieve considerable material degradation. Land application of finished material is currently not approved for either system. According to Hill and Baldwin, finished material from MLMC systems should continue onto a biosolids treatment facility to further stabilize. SSVC units use a newly acknowledged treatment for waste treatment and process conditions have not yet been developed to approve land application.

In conclusion, Hill and Baldwin strongly recommend SSVC units over MLMC units for a variety of reasons listed below.

- Consistently low E. coli counts in end-product
- Minimal operational hazards involved
- Minimized fecal contaminated leachate
- No bulking agent necessary
- End-product decomposition by 41%
- Low free-ammonia levels
- Abundant nitrate levels

Through email correspondence with Geoff Hill, he shared that he has designed several urine diverting composting toilet systems. He believes that liquid waste is a more valuable fertilizer with simpler and safer handling requirements than solid waste, almost to an extent to focus only on liquid waste.

References:

Hill, Geoffrey B. & Baldwin, Susan A. (2012). Vermicomposting toilets, an alternative to latrine style microbial composting toilets, prove far superior in mass reduction, pathogen destruction, compost quality, and operational cost. *Waste Management*, 32, 1811-1820.

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Manufacturer Websites

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