Guidance for Composting Toilet and Greywater Systems in BC

Version A

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Canadian Onsite Technical Resource Association (COTRA)

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A Introduction

The purpose of this guideline is to support the BC Ministry of Health *Manual of Composting Toilet and Greywater Practice*. This guideline provides background and educational information and resources that are consistent with the approach of the Manual. The guideline is intended for Authorized Persons, owners and other interested parties.

The guideline provides:

- Introductory and background information on composting processes
- Specific information on types of composting toilet systems, with links to online resources
- Checklists for planning a composting toilet system
- Background information on greywater characteristics and the application of greywater to soils
- Educational material for homeowners, including source control information

This material collects information from previous COTRA literature review and discussions, together with material developed specifically to support the Manual. This guideline is in draft form, COTRA intends updating the guideline over time, and welcomes feedback and recommendations for added materials.

Particularly, proponents of and experts in particular techniques are encouraged to contact COTRA with corrections to process or unit descriptions or with options that are not covered.

The Manual of Composting Toilet and Greywater Practice is referred to as “the Manual” in these guidelines. Information in the Manual is not repeated in this guideline. Prior to reading the guideline the reader should, at minimum, read the introductory material in Part A of the Manual. The introductory material includes flow charts that are necessary to understand the content of this guideline.

The Manual includes reference to design manuals, recommended reading and online resources. The rationale appendix of the Manual includes references to an extensive bibliography of technical literature. The Manual is itself based on the BC Sewerage System Standard Practice Manual Version 3 (SPM), and a familiarity with the approach and standards of the SPM is necessary for use of the Manual.

For general information on alternative waste and wastewater systems the following online resource is recommended as a starting point:

Sustainable Sanitation and Water Management (SSWM) Toolbox http://www.sswm.info/

B Composting toilet systems and processes

B- 1 INTRODUCTION

This section summarizes common composting processes and identifies key performance constraints.

B- 1.1 Typical purposes for non-waterborne excreta management

Common reasons or basis for choosing a composting toilet system include:

- Climate constraints for sewerage system
- Site and soil constraints for sewerage system
- Water conservation
- Water scarcity:
- No water supply available (common at parks, rest stops)
- Very limited water supply (e.g. low yield well, rainwater harvesting)
- Reduction of volume and mass of waste, for removal off site (e.g. at remote site)
- Marine craft, reducing space for holding tank and widening discharge options as well as water savings
- Nutrient reclamation and organic matter recycling, may be in combination with composting of food wastes and garden wastes
- Bioremediation of pharmaceuticals in the composting system
- Philosophical or life style choice

B- 1.2 Primary objectives for a composting toilet system

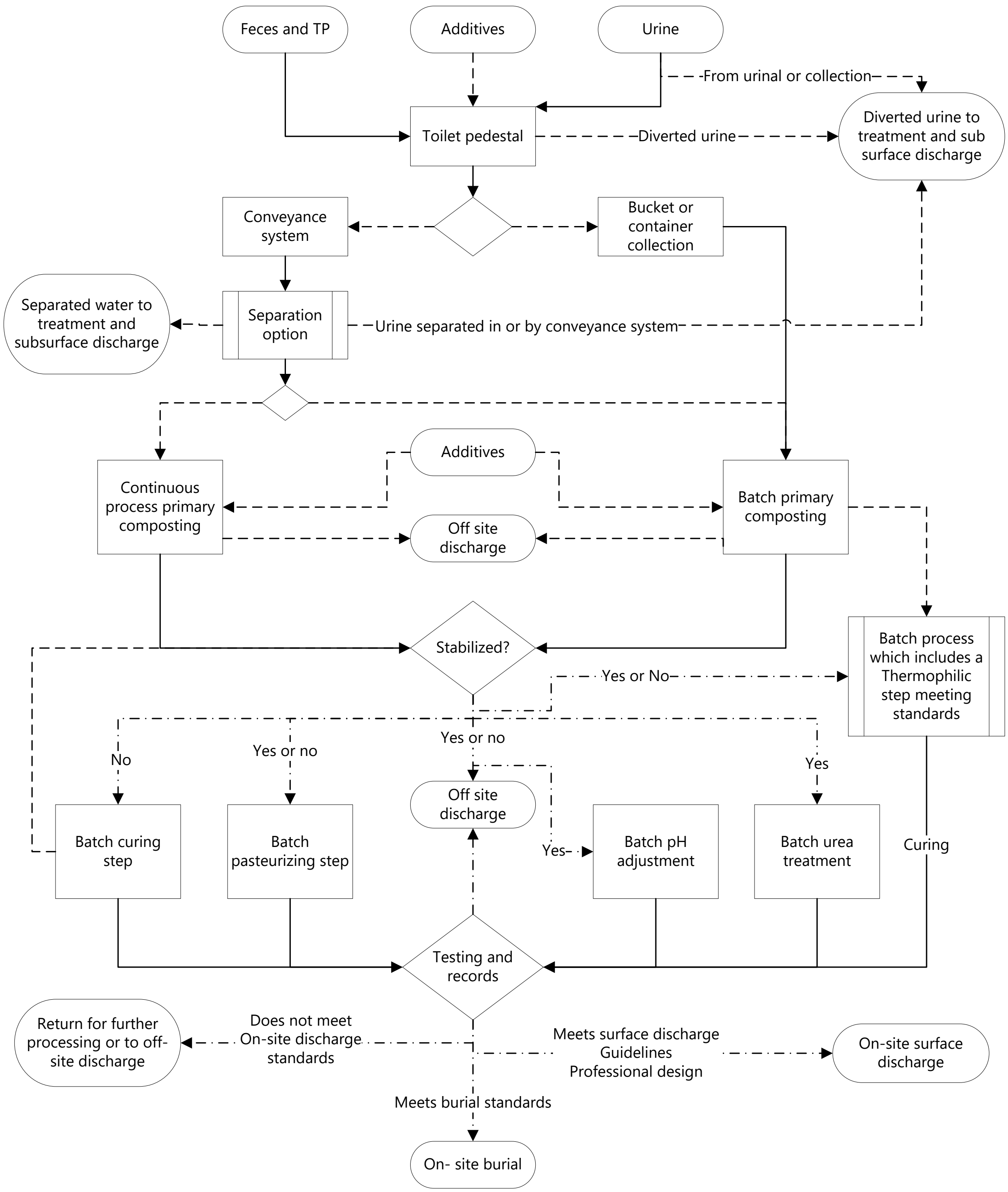
The specification and use of composting toilet systems is highly varied, but all systems share the primary purposes established by the Manual:

- Safely and hygienically collect and contain human waste
- Manage odors and prevent vector or human access during storage
- Manage leachate and safely discharge leachate or diverted urine to a combined or source separated wastewater sewerage system
- Provide for safe and practical management of residual organic matter

B- 1.3 Flow chart illustrating composting toilet processes and options

The flow chart shown in Figure B- 1 is intended to illustrate the general options for application of composting toilet systems, showing different processing, curing, sanitizing and discharge options.

Figure B- 1. Composting toilet systems



This chart does not show every available option. Particularly, the chart does not show:

- Details of process, e.g. leachate management, heat input, ventilation, type of composting phase, vermicomposting.
- Pre-treatment options, e.g. fermentation, pre-process pasteurization, dry toilet systems
- Container collection to separate continuous process composting
- Various forms of batch process, e.g. dedicated container, pile
- Incineration option at toilet or for residual organic matter

B- 2 AEROBIC PROCESSES

Composting toilets with processors which are designed to achieve stabilization of human waste (rather than primarily to safely store human waste) are normally based on aerobic composting, with or without addition of bulking agents.

Aerobic processes (oxygen content in all parts of the compost over 5%):

- Psychrophilic, also termed ambient or mouldering, at ground temperature, 20 C or less. Involves bacteria, actinomycetes, fungi, protozoa and macro fauna. Fungi and actinomycetes dominate the microbial community. Typical of conditions in passive mouldering composting processors, and may also be the dominant regime in other processors not operating as planned. Also typical of conditions during later stages of batch curing.
- Mesophilic, 20 to 40 C. Involves mesophilic bacteria, actinomycetes, fungi, protozoa and macro fauna. Typical of conditions during curing and higher temperature phase in non-thermophilic composting processers.
- Thermophilic, over 35 C. Primarily bacterial, but with some thermophilic or thermotolerant fungi and actinomycetes.

Composting does not occur in a single step. A typical batch will go through:

- An initial mesophilic phase
- A thermophilic phase
- A cooling, second mesophilic phase
- A long mesophilic to psychrophilic curing (maturation) stage.

Phases or steps may also be physically separated, for example, a continuous process mesophilic processor with separate batch psychrophilic curing step.

Although true “composting” requires a thermophilic phase, the term “composting toilet” is generally used in the industry to refer to processes that do not achieve this phase of composting, including, for example, mouldering processors.

For thermophilic processes, typically processes result in a thermophilic step, followed by a curing stage. It may be practical to take residual organic matter that has been treated by a long curing period and bring the material to a thermophilic stage to complete stabilization and pathogen reduction through mixing or other methods. In this case part of the curing period specified by the standards can take place prior to the thermophilic step.

B- 2.1 Requirements for aerobic composting

B- 2.1.1 TEMPERATURE

Adequate temperature is necessary, and in the cold season a heat source may be needed. Some composting processors use heaters to assist in providing mesophilic or thermophilic conditions.

In extreme cold climate conditions, compost may freeze in the processor or during curing. This lengthens the curing process, but is not necessarily detrimental. The Manual specifies a longer curing process where temperatures drop for significant periods below 5 C (the effective lower limit for biological activity).

B- 2.1.2 AIR AND GAS EXCHANGE

To ensure adequate gas exchange and keep the compost aerobic various techniques are used, including:

- Active, with mixing, manual or motorized (mixing also helps to give all parts of the compost time at temperature)
- Passive, aeration with screens or pipes (venting is also used for vector and odor control)
- Blowers or fans either blowing or sucking air through the composting materials
- Addition of bulking agents to improve structure and porosity

Active processes tend to increase "cost", either energy or operator time, and may need more maintenance. Manual turning of piles can lead to aerosolization of particles and risk from inhalation (particularly aspergillus spore risk). Turning and mixing compost can cause heat loss.

The Manual refers to the USDA Sweet Smelling Toilet ventilation method. Another resource for ventilation system information is the SOPAC Design Examples of Waterless Composting Toilets (1997), available at: http://www.pacificwater.org/userfiles/file/mr0249.pdf

B- 2.1.3 MOISTURE

All composting processes require adequate moisture—typically 45 to 70% moisture content. At low moisture content biological activity will slow or stop and at high moisture content the compost will be at risk of becoming anaerobic. During active composting water may need to be added, or rainfall input may be allowed. During collection excess moisture may be discharged as leachate, or bulking agents added to reduce moisture content. In some cases leachate may be recycled to wet composting materials. Management involves maintaining a balance, and for some units this may require daily intervention.

B- 2.1.3.1 Assessing moisture content

Moisture content of composting material is most accurately evaluated by weighing a sample of moist material, drying and then re weighing.

For rapid assessment during initial composting a simple moisture meter probe can be used. Visual inspection will also indicate whether the material is too wet or too dry:

- Too wet, visible liquid in the processor, anaerobic odor.
- Too dry, feces and toilet paper visible and building up, degradation not occurring.

For rapid assessment of composting material during the curing step the squeeze test is accurate enough (within 5%) for management purposes.

Squeeze a representative sample of compost between your hands (wear gloves and follow minimum hygiene practice standards specified the Manual):

- If the squeezed material crumbles, does not hold together and your gloves feel dry, moisture content is at 40% or less.
- If the squeezed material sticks together and your gloves feel moist, moisture content is approximately 50%
- If the squeezed material sticks together and water drips out, the material is at 60% or above.

The behaviour of composting toilet materials varies, depending on type of process and bulking agents, so these simple tests and inspection should be adapted to your experience with the particular process. This experience can be used more accurately if based on testing of samples.

B- 2.1.4 CARBON TO NITROGEN RATIO

For composting, a suitable Carbon to Nitrogen (C:N) ratio is preferred. C:N ratio is measured as % total organic carbon to % total nitrogen. Target C:N ratio for composting processes is typically between 20:1 and 30:1. When urine is diverted or drains to the base of the processor as leachate, C:N ratio of the remaining feces is between 5 and 11. This means that some added high carbon matter will reduce nitrogen loss and result in more rapid composting. However, lower carbon levels may also lead to improved bioremediation of some complex organic contaminants, and ratios as low as 15:1 have been demonstrated to be successful for composting of manures.

When urine is included with feces, the C:N ratio is lowered further. This is because the majority of nitrogen in excreta is in the urine.

Aerobic composting processes often involve addition of high carbon bulking agents, however these are added primarily to absorb moisture (where urine is not diverted) and to maintain permeability of the compost in the processor.

Common bulking agents do not provide an effective carbon source since little of woody biomass is actually bio-available, so are not effective at adjusting the C:N ratio. As a result, the primary functional impact of this bulking is to improve structure and aeration, and also to increase volume. Volume increase may reduce the holding time in the chamber if the system is not carefully sized to include added bulking agent, which will increase the frequency of residuals removal and so may increase the hazards associated with those activities.

Processes which divert urine and use little or no bulking agent (e.g. urine diversion vermicomposting toilets) are more likely to meet volume and mass reduction objectives.

B- 2.2 Vermicomposting and Black Soldier Fly composting

Vermicomposting or BSF (Black Soldier Fly) composting are special forms of aerobic composting, where macro fauna are used to assist in digestion and aeration of the organic matter. Thermophilic temperatures are typically avoided (as these will kill the macro fauna).

Both techniques are used in composting toilet processors, typically combined with urine diversion. Vermicomposting may be used to compost absorbed leachate from BSF composting processors. Vermicomposting is more common in colder climate conditions.

Processes may be specially designed for vermicomposting, or worms may be added to other processor designs to assist with aeration and digestion. Worms have been successfully used in sloping floor continuous processors, batch bin processors and other systems.

B- 2.2.1 THE VERMICOMPOSTING PROCESS

The worm most suitable for human waste composting is Eisenia foetida (Red Wiggler). Although smaller (5 to 10 cm at maturity) than most other compost worms, this species multiplies quickly and can tolerate a wide range of temperature. They will quickly reproduce to create a large overall biomass in relation to the compost mass that they inhabit. E. Foetida consume one half of their body weight every day under ideal environmental conditions.

For further background information on vermicomposting refer to:

G. Munroe, '*Manual of on-farm vermicomposting and vermiculture*', Pub. of Organic Agriculture Centre of Canada, vol. 39, 2007. http://oacc.info/docs/vermiculture_farmersmanual_gm.pdf and to

http://lockyervalley.org/2013/05/21/diy-composting-toilet-with-worms/

B- 2.2.1.1 Earthworm purposes

Function of earthworms:

- Worms create channels in the compost mass by their burrowing activity, allowing air to penetrate into the pile as well as encouraging drainage.
- Worms consume and digest living organisms such as nematodes, protozoans, rotifers, bacteria, fungi in soil. By consuming pathogenic bacteria they hasten the pasteurization process.
- Earthworms increase the rate of volatile solids reduction.
- Reductions of odours.

The by-product of worm metabolism is humus in the form of worm castings, which are rich in nutrients and a wide variety of microorganisms. The castings are considered to be a valuable soil amendment.

B- 2.2.1.2 Process requirements

Optimal Environmental Conditions for E. foetida:

- Temperature 15-20C (Limits 4-30C), but cocoons can survive freezing
- Moisture content 80 – 90% (Limits 60-90%)
- Oxygen requirements Aerobic environment
- Ammonia content of waste Low: <0.5mg/g
- Salt content of waste Low: <0.5%
- pH >5 and <9

Creating optimal conditions for earthworms in the composting process is enhanced by:

- Ensuring good air flow around compost mass and if possible under the mass
- Ensuring positive drainage so that the mass is never saturated
- Dark environment, as the E. foetida is photosensitive
- Minimizing urine – Minimal urine is acceptable so long as ammonia content is not above 0.5 mg/g and salt content is not above 0.5%
- Avoiding addition of ash or lime

- Providing a refuge for worms, for example to allow them to escape high ammonia conditions in newly added excreta

Ammonia and salt build up can be mitigated by way of a fresh water micro-spray on a timer used to flush the pile on a limited basis of a few times a week for short durations, being sure not to create saturated conditions.

Diatomaceous earth (often used to combat insect vectors in composting toilet systems) does not harm annelid worms. Only food grade diatomaceous earth should be used. Neem oil in small quantities also may be safe for use with worms, but should be tested on a trial basis.

As well as composters specifically designed for vermicomposting, worms may be added to a variety of composting processors to assist with digestion and aeration. They have been successfully used in batch bin composters, sloping floor continuous processors, horizontal chamber composters and vertical composters.

B- 2.3 Key performance constraints for the composting process

As with small scale treatment systems for residential sewage, small scale composting of human waste is challenged by wide fluctuation in use, both from facility to facility and for a single facility from day to day.

Operational and maintenance intervention is needed, and poor operation or lack of maintenance will lead to poor performance.

Low temperature conditions reduce microbial activity and, again, with small systems heat loss is proportionally higher due to a large surface area to volume ratio.

Control of moisture levels is difficult where urine is collected with feces, and excessive moisture and ammonia has been identified as a key factor in poor performance of small systems and public use systems. For small systems with heaters and effective ventilation, too low moisture content can result in drying rather than composting. Poor aeration of the composting material is commonly worsened by excessive moisture.

As a result, it is unusual for small, residential, composting processors to reach and maintain thermophilic temperatures for an adequate period to result in sanitized residual organic matter.

Other common constraints include:

- Difficult or limited access for maintenance.
- Structural issues and failures, corrosion.
- Electrical issues.
- Inadequate venting or ventilation.
- Failure of sealing or screening or venting resulting in vector access to or travel from waste.
- Infiltration of groundwater.
- For continuous process processors, contamination of partially stabilized material by fresh excreta or leachate.

These constraints may lead to risk. In general, risk related to the primary objectives for the composting toilet is more easily managed by proper equipment specification and installation—following the standards of the Manual.

Risk related to secondary (process) objectives for residual organic matter can only be successfully managed if proper operation and maintenance is undertaken.

The Manual addresses risk of incompletely stabilized residual organic matter by:

- Identifying residual organic matter as a potential biohazard regardless of treatment method.
- Specifying standards for lowering handling risks.
- Specifying a base option of off-site discharge to an approved facility.
- Specifying a batch sanitizing step or batch long term curing prior to on-site burial.
- Specifying standards for on-site burial.
- Specifying testing standards and other requirements for land application
- Oversight by an Authorized Person.

When specifying a composting toilet system, the AP should consider these common performance constraints and the capacity of the owner and maintenance provider to address potential issues. This is particularly the case when on site discharge of residual organic matter is planned. This is similar to selection of a treatment system for sewage.

The following system specifications have generally been found to improve system performance:

- Urine diversion
- Simple systems
- Insulated or in house systems
- Systems with adequate ventilation
- Systems with large, easy and hygienic access provisions
- Systems with adequate maintenance and monitoring
- Situations where the owner understands and takes ownership of the system, participating in operation and maintenance

B- 2.4 Insect control

Of all vectors of concern in composting toilet systems, insects and arthropods are the most difficult to completely eradicate. These organisms often are beneficial to the process and only become vectors if they can escape from the collection system or processor and carry contamination to the living space or to food.

Control starts with proper specification and maintenance of sealing and screening. Ventilation systems are important. Avoiding buildup of uncovered excreta in the collection system is also critical. Other strategies include:

- Screen windows and or doors and ventilation openings in the building
- Compost additives can deter flies
- Covering collection pile with a thin layer of compost or compost rich soil
- In some systems, avoiding adding fruit scraps which may breed fruit flies and attract other flies
- Keep compost moisture content optimum
- Arrange venting to act as a fly trap, since flies typically move toward light and will be trapped at the top of screened vent pipes if that is the only light they can see (toilet seat must be kept shut)

- Install a fly trap in the pedestal or processor which works on the principle of attraction to light, with a plastic bottle or similar to trap the flies
- Use fly strips or other sticky traps
- Diatomaceous earth (food grade only) can be sprinkled on the inside surfaces of collector chutes etc. to kill insects
- Neem seed oil has been used to control insects
- Insect growth regulators and other specific pesticides
- Pyrethrin sprays and other insecticides may be used, with the normal concerns and precautions

B- 2.5 Aerobic composting toilet system types

Table B- 1 outlines the main types of aerobic composting toilet systems. In all cases there is the option of urine separation. This table is intended for orientation and illustration, and should not be taken as excluding a process or toilet type that is not specifically mentioned. See Section C for discussion of specific types of composting toilet system.

The excreta is deposited into a composting toilet pedestal. This may be a raised pedestal, a squatting plate or other suitable system.

In the case of feces separated by filtration or other method from blackwater, or in the case of a vacuum collection system, the role of the composting toilet pedestal and collection system is taken by the sanitary drainage system and separator or by the vacuum system. In some cases, the separated fecal matter and toilet paper (or the material from the vacuum system) are discharged direct to a composting processor, but they could also be discharged to a container and taken to a separate processor.

Separate processors are typically batch type, but could be continuous type.

Additives used vary depending on specific system design.

For continuous and batch processes, vermicomposting or black soldier fly composting are potential options. Where temperatures are in the psychrophilic range fungal treatment systems may be integrated to the composting process, even to the point of replicating a “forest floor” ecosystem.

Collection and processing can include several steps; each may have a different type of process. For example, a commode system could include a microaerobic fermentation step prior to conveyance to a batch composting processor.

Depending on planned discharge method for residual organic matter, a curing or sanitizing step may be used. In all cases this is a batch step and may be used with any system.

For all types of system external heat source may be used to provide a sanitizing step, either by assisting in reaching thermophilic temperature for adequate time, or by reaching pasteurization temperatures. This approach is less common for open source systems and commode systems.

Vault and dry toilet systems are not included in this table, but may be used as a combined pedestal and storage system, with collection and conveyance similar to the commode system, followed by batch compost processing.

Table B- 1. Main types of aerobic composting toilet system

<table>
<tr><th>COMMODE BATCH</th><th>CHAMBERED BATCH</th><th>CHAMBERED CONTINUOUS</th><th>STEP OR NOTE</th></tr>
<tr><td>o Falls to collection container
o Typically buckets or bins
o Ventilation for odor and moisture control
o Lid typically sealed to pedestal</td><td colspan="2">o Falls to processor chamber or container
o May be conveyed by short length of pipe and small amount of water or water plus additive
o May be conveyed by a vacuum collection system</td><td>Collection</td></tr>
<tr><td colspan="3">o Bulking or other additive may be added at collection, often applied per use.</td><td>Additive at collection</td></tr>
<tr><td>o Collected material transferred to separate processor
o A dedicated series of composting piles, bins or containers
o Materials added to pile, bin or container until specified size reached
o Batch composted and matured
o Active mixing during thermophilic step
o Leachate storage and collection system</td><td>o Collected material processed in chamber or container
o Carousel
o Separate vaults
o Separate containers
o May be passive or active (mixing)
o Leachate storage and collection system</td><td>o Single chamber
o Bulking agent added
o May be passive or active (mixing)
o Leachate storage and collection system</td><td>Primary processor</td></tr>
<tr><td>o Typically to reach thermophilic or at minimum mesophilic temperatures
o Monitored for time at temperature</td><td>o May reach mesophilic temperatures, or may be almost entirely psychrophilic
o May be managed to reach thermophilic temperature
o If appropriate, monitored for time at temperature</td><td>o May reach mesophilic temperatures, or may be almost entirely psychrophilic, particularly for small, residential units
o May be heated to reach thermophilic temperatures.
o Risk of recontamination of stabilized material by new additions of excreta</td><td>Thermophilic sanitizing step</td></tr>
<tr><td>o In same pile, bin or container.</td><td>o In same container or chamber, may be moved to separate location.</td><td>o In separate batch process</td><td>Curing (if used)</td></tr>
</table>

COMMODE BATCH	CHAMBERED BATCH	CHAMBERED CONTINUOUS	STEP OR NOTE
○ Residential ○ Residential seasonal ○ Smaller public use sites with frequent servicing ○ Peak usage dictates servicing cycle	○ Residential ○ Residential seasonal ○ Public use with infrequent servicing ○ Peak and average usage dictates chamber or container change interval ○ For some methods servicing requires closing facility	○ Residential ○ Residential seasonal ○ Public use with moderate servicing ○ Multifamily residential or commercial	**Typical usage**
○ Resident ○ With AP supervision	○ Resident ○ With AP supervision	○ Small systems, resident with AP supervision ○ Larger systems, trained operator	**Operator and maintenance provider**

Anaerobic digestion may take the part of one or more of the composting process steps.

B- 3 MICROAEROBIC

Microaerobic processes occur when oxygen levels are very low. The process is one of fermentation, with lactic acid bacteria and yeasts.

Bokashi composting and Terra Preta Sanitation (TPS) (http://www.sswm.info/content/terra-preta-sanitation-0) are two common methods that use a fermentation step. In the case of TPS the fermentation step is part of commode collection and is followed by aerobic composting with bio-char or charcoal addition.

B- 4 ANAEROBIC

Anaerobic digesters are an alternative to aerobic composting and the residual organic matter from the digester may be taken to a composting step to further stabilize the digested organic matter.

Anaerobic digestion may be either mesophilic or thermophilic. In the case of thermophilic digestion residual organic matter may meet standards for on-site discharge without further composting.

A septic tank is also a primarily anaerobic system. Dewatered septic tank sludge may be composted.

B- 5 DRYING

Drying is a non-composting process which partially stabilizes feces by natural, convection draft or artificial draft drying, heat assisted drying etc. The storage container of a dry toilet is not normally a composting process. The stored material is not normally stabilized, and there is a risk of pathogen re-growth.

For these reasons the dried excreta is suitable only for off-site discharge unless it undergoes further treatment (e.g. composting in a separate batch processor). Drying toilets also may serve as collectors for incineration systems.

B- 6 DISINFECTION AND SANITIZING

Composting may be followed by a sanitizing or disinfection step, or disinfection may be included as a part of the composting process. Incineration also provides sanitizing.

B- 7 RISK FROM COMPLEX ORGANIC POLLUTANTS

Urine streams contain the majority of hormone and pharmaceutical product contamination, however some of these contaminants will also be found in feces. APs should consider the potential uptake of these complex organics by vegetation that is grown on or near buried residual organic matter.

In general, the breakdown and removal of complex organics is improved with long term composting, and with higher temperature during composting. Co-composting of urine with woody wastes, particularly where a long psychrophilic step is used and fungal activity is encouraged, may assist in breakdown of complex organic contaminants in the urine.

B- 8 SOURCE CONTROL

Residential toilet system do not normally suffer from trash disposal, which is a key concern for public use toilets.

It is important for the owner and users to understand the potential impact on the composting process of:

- Antibiotics, which can affect the composting process
- Vermicides, which will kill worms in a vermicomposting process
- Cleaning chemicals, which can affect the composting process (see Section F- 1.3, page 57 for further information on cleaning chemicals)

The composting process will not be severely impacted by feces from an individual taking antibiotics, due to dilution of the relatively small amount of antibiotic in feces. However, drugs should not be disposed to the composting toilet.

C Types of composting toilets

C- 1 INTRODUCTION

When selecting a composting toilet system or process, it is important to consider advantages and disadvantages related to the site and use, and particularly related to the owner or operator's capacity.

The *"Composting Toilet System Book"* and *"Ecological Sanitation"*, referenced in the Manual, and the SSWM website (see Section A above) provide guidance on selection and summaries of the advantages and disadvantages of particular units or technologies.

GIZ has published Technology Review of Composting Toilets (2011):

http://www.berger-biotechnik.com/downloads/gtz2011-en-technology-review-composting-toilet.pdf

These and other referenced design manuals also provide general information on operation and maintenance of the systems. The SSWM website includes references to online resources for open source systems and design manuals for each specific technology. When reading manuals, consider the climate in the location the manual is written for, the performance of particular composting and digestion processes in tropical climates may be widely different than those in cold climate locations.

This Section presents information summarized from these design manuals and other literature sources, to assist in selection and specification of a composting toilet system. **Information in this Section should not be taken as endorsement or criticism of any particular technique.**

For proprietary systems the AP should also consider manufacturer information and any testing and certification for the specific unit. **Examples** of manufacturers are included for each type of toilet, the list is not exhaustive and other manufacturers may supply similar systems.

For open source systems the AP should consider design manuals and information for the specific system. Where available, web references are provided in this Section. Not all open source or proprietary systems are covered in this Section.

Sizing information is provided for scoping only, the Manual specifies that the AP size the composting toilet system on a site and project specific basis.

The information in this Section is primarily for residential composting toilet systems. In specific cases additional notes are provided on application to public use sites. For signage, off-site discharge, wood fired incineration and other information relevant to remote public use sites, refer to the Appalachian Trail Conference Backcountry Sanitation Manual, available at:

http://atfiles.org/files/pdf/atcsanitation.pdf

C- 2 URINE DIVERSION SYSTEMS

Urine may be diverted from water closets or composting toilets using a variety of methods.

See http://www.sswm.info/content/urine-diversion-components

Proprietary urine diverting seats or pedestals may be specified as part of an open source composting toilet collector system. Examples are diverting seat systems by Separett (http://www.separett.ca/) or C-Head (www.**c-head**.com/).

When specifying a diversion system as part of a new toilet or as a retrofit, consider maintenance and cleaning requirements based on the type of use. Consider safety of maintenance providers and users.

Where practical, use urinals or another separate collection method to divert urine from the wastewater stream. This will result in less fecal contamination, reduced maintenance and easier user acceptance. Urinals appropriate for male, female and unisex use are available. Water-borne urinals can be converted to waterless urinals by the replacement of traps with silicone curtain valves.

Waterless urinals do not use water filled traps. In order to prevent odors and or sewer gases from collection piping exiting through the urinal it is necessary to install an odor trap. Various trap styles are available, common options are:

- A trap or cartridge using urine plus a sealant liquid, typically a vegetable oil or aliphatic alcohol. The trap may also include some microbial inoculant to reduce odors. The cartridge may be replaceable or may be able to be cleaned and re used.
- Self-sealing membrane valve or curtain valve. Silicone curtain valves typically require less frequent replacement or maintenance.

Less common options include ball valve based systems, air enclosing traps and hydrostatic float barriers.

If the urine is to be stored, avoid specifying a system that requires regular flushing with large volumes of water since this will result in diluting the urine.

For collection containers or for discharge to a storage container from smaller collection containers an odor trap is used, in this case typically a silicone curtain valve is used but an improvised valve or ball and funnel arrangement may also be used.

When specifying odor traps, consider the level of use the urinal or collector will be serving and the need for maintenance. Some trap systems are more appropriate for high use fixtures; others may suit residential use better. Cost for replacement cartridges may be higher than for cartridges that can be cleaned and re used. Likewise, consider cost and frequency of replacement for self-sealing valves.

C- 2.1.1 URINE STORAGE AND PATHOGEN REMOVAL

To effectively sterilize stored urine at typical ambient or house temperatures it is necessary to allow a minimum of 6 months storage, during which time temperature of the stored urine should be at or above 20 C. At higher temperatures, shorter storage periods are needed. For example, at 30 C, 2 months will provide adequate sanitizing.

As the Manual requires subsurface discharge of stored urine, less stringent time and temperature requirements are specified by the standards. Higher temperatures will improve pathogen removal. A professional may specify a shorter storage time at a higher temperature.

Dilution of stored urine reduces the sanitizing effect of ammonia. Ammonia content target is minimum 2.8 g/L (as N) and pH of 8.8 or higher. Dilute the urine just prior to use, not prior to storage.

A sealed container is specified to avoid loss of ammonia and to reduce odor issues.

C- 2.2 Specification notes

Typical features and specifications include:

- Urine diversion by way of waterless urinals and or urine diverting toilets.
- Urine may be discharged or may be stored for a period of time and then dispersed during the growing season.

Urinals or urine diversion are recommended for incinerating toilet systems and drying toilet systems.

C- 2.3 Sizing

Receiving chambers or bins for solid waste can be sized smaller because less volume is collected, volume of bulking agent will be less as this is normally added to absorb urine in the collection bin or chamber.

Urine storage tanks are sized following standards in the Manual.

C- 2.4 Pros and cons

Pros:

- Urine diversion reduces the volume of human waste and reduces the volume of bulking agent needed
- Urine and feces need different treatments, separation may improve treatment
- Reduces ammonia levels in waste, which increases range of composting options (e.g. more favorable conditions for vermicomposting)
- Reduces odour
- Prevents excess humidity in the processing vault, improving aeration and reducing need for leachate management and or heating of the process
- Improves probability of achieving thermophilic composting phase
- Diverted urine remains relatively free from pathogenic organisms
- Uncontaminated urine or urine sanitized by storage is a useful fertilizer

Cons:

- Urine diverting toilets risk contamination of the urine with fecal matter
- Maintenance of the urine diverting toilet and urinal adds to system maintenance needs
- For some in toilet diversion systems, user training is needed
- A separate collection system is needed for the urine
- A urinal requires more space in the toilet room
- In some processes, water may need to be added to the solid waste to provide moisture needed for composting
- A discharge method is needed for the diverted urine, and diluting water may be needed for discharge

C- 2.5 Risks to avoid

Odours from waterless urinals, suitable sealing method is needed to prevent gases from sanitary drainage piping entering the room.

C- 2.6 Process challenges and solutions

Buildup of mineral precipitate can occur in pipes.

- Use minimum 2" drain lines with adequate access for cleanout.
- Flush or wash down waterless urinals with hot water with acetic or other acid occasionally. Do not discharge excessive amounts of acid or wash water to the urine storage container.

C- 2.7 Urine composting

Urine may be separately composted. This is typically by co-composting with wood fiber, but several methods are available.

A struvite process may be used to precipitate struvite from urine. The resulting struvite is used as a fertilizer. One advantage of this approach is that complex organics primarily partition to the liquid phase, with little contamination of the struvite product. For further information see:

http://www.sswm.info/category/implementation-tools/wastewater-treatment/hardware/processes/struvite

C- 2.8 Urine diversion at public use sites

Urine diversion may be highly beneficial for public use toilets, since public use sites typically receive higher proportion of urine to feces. Literature indicates that a key cause of malfunction for public use composting toilet systems is excessive urine loading.

Some diversion systems are not appropriate for public use. Generally, systems where training or detailed instruction is needed are not suitable.

Waterless urinals provide the simplest method of diversion for public use toilets, and avoid the user familiarity and maintenance issues with in toilet diversion systems.

Proprietary technologies used in public use toilets divert urine as part of the pedestal or conveyance system either by:

- Urine diverting pedestal
- Wiper mechanism
- Conveyor belt system, with feces and toilet paper discharged to the composting processor and urine diverted (see Section C- 5.7, page 42)

Another example of a urine diverting toilet pedestal intended for public use sites is made by NatSol in the UK:

http://natsol.co.uk/urine-diverting-compost-toilets/ outlines the rationale for development of the diversion pedestal.

C- 3 COMPOSTING TOILET PEDESTALS AND CONVEYANCE SYSTEMS

A wide range of manufactured options are available for toilet pedestals. Conveyance systems are also available, ranging from chutes to micro flush toilets to foam flush toilets to vacuum systems. Some small batch bin systems may be used as collection systems, with collection in containers or bags.

In many cases open source systems utilize manufactured pedestals and or conveyance systems. The *Composting Toilet System Book* provides a useful summary of some of the available options. See above for urine diverting pedestal systems.

C- 3.1 Dehydrating toilets

Also termed urine diverting dry toilets (UDDT).

See: http://www.sswm.info/category/implementation-tools/water-use/hardware/toilet-systems/uddt

These toilets are similar to double vault toilets, but receive no urine or water. Toilet paper is not added to the toilet but is disposed separately. The Manual does not consider residual organic matter from drying toilets to be suitable for on-site discharge, but provides for them to be used as a collection and storage system for human waste (for off-site discharge or incineration) and specifies that the dried material may be composted after collection and drying. Incineration is also an option after collection and drying.

Ash or lime is, in some cases, added to raise pH and improve desiccation. This is not recommended if the material is to be composted. Earth, charcoal or bio-char may also be added. Pathogen reduction in drying toilets increases with increasing ambient temperature and pH.

Composting does not take place with dehydration. If buried, soil moisture conditions will rehydrate the material and start the composting process in the soil, which will have phytotoxic effect on vegetation. Pathogen regrowth may also occur. This is the reason that the residual organic matter from these toilet systems is not considered suitable for on-site discharge.

A household of 5–6 persons will produce approximately 0.5 cubic metres of dehydrated material per year. The small volume of dry, odorless, waste is advantageous for off-site discharge, particularly where transportation is difficult.

C- 4 BATCH COMPOSTING TOILET SYSTEMS

C- 4.1 Open source double vault toilets (fixed batch)

The *Composting Toilet System Book* discusses and gives references to several open source designs of this type. One example is the Sunny John: http://www.strawbalecentral.com/cinva/sunnyjohn.html

C- 4.1.1 SPECIFICATION NOTES

Typical features and specifications include:

- Sealed, water proof chambers. Concrete block construction as well as poured concrete should have inside surfaces sealed with waterproof mortar parging or other effective sealing method.
- Toilet usually situated directly above chamber but can be remote if connected to a micro flush, foam flush or vacuum toilet.
- Vented for odour elimination as well as to provide oxygen to enhance composting, following USDA Sweet Smelling Toilet guidelines.
- Target 45 to 70% moisture content.
- One vault is collecting fresh excreta while the second vault composts.
- Before the initial use the vault floor is normally lined with a layer of straw or other organic bedding as well as a layer of top soil or compost as a filter and an inoculating starter.
- Access hatches adequately sized and placed to allow easy and safe removal of residuals.
- Used with or without urine diversion but more effective without urine.
- Drain for leachate and urine to evaporation, collection, or leach area.
- Organic bulking agent usually added after each defecation for liquid absorption and aeration.
- Floors can be inclined or flat but if “flat” have a minimal slope towards the leachate drain.

C- 4.1.1.1 Other considerations

Switching to the alternate bin can be done by way of, moving the toilet pedestal, if allowed for in design, swivelling drain pipe from micro flush toilet, or shovelling the compost pile to the adjacent bin. Separate pedestals may also be used.

Moving the pedestal, or the use of separate pedestals, is the easiest but is dependent on enough room being available in the room to allow for this.

Moving the pile mixes the fresh material with the more composted and introduces short term thermophilic temperatures. However, this process creates a possibility of maintenance person contact with un-composted material and possible health hazard. Protective measures must be taken.

If a micro-flush toilet is used this creates possibility of too high moisture content in the compost and leaching of the compost.

C- 4.1.1.2 Alternative double vault

Net Collection in bins or vaults is an option. In this approach, nets hung in bins collect the excreta. This allows for good drainage and aeration.

However, it is awkward to handle nets full of compost when removing, and there is an increased chance of contact between maintenance provider and the residual organic matter.

C- 4.1.2 SIZING

Sizing is based on number of full time users (or adjusted for part time users). Size chambers to receive fresh waste for the same length of time as the planned composting process. For example, if the process is expected to take 20 months for composting plus curing the chamber should have a minimum capacity equal to 20 months accumulation plus headspace.

As adding capacity may be difficult, it is recommended that the AP use a conservative capacity estimate.

Example of sizing:

Four people using bulking agent for each defecation and collecting feces and urine, but with the majority of urine draining away as leachate. Target of 20 months composting and curing prior to removal of residual organic matter.

For each person, fecal volume per day of 0.18 L and bulking agent of 0.5 L, total 0.68 L/day. Four people will produce approx. 1.6 m^3 of combined excreta and bulking agent in 20 months (see example in the Manual). Allowing for 40% reduction in volume, after 20 months accumulation and composting volume equals 1 m^3. Size each chamber to be minimum 1.5 m^3 in volume.

Added volume may be needed for headspace, and for starter material at the base of the chamber. Volume depends on layout of the system. Typical chamber size for 4 persons is 1.2 mx 1.2 m x 1.2 m (1.7 m^3 total capacity).

C- 4.1.3 PROS AND CONS

Pros:

- Simple system with no mechanical components.
- Effective mouldering process at mesophilic and psychrophilic temperatures provide adequate sanitizing and stabilization given a lengthy time for stabilization. 1.5 – 2 years is needed, depending on moisture and temperature.

Cons:

- Thermophilic temperatures usually not achieved but this type of system may be managed to reach these temperatures.
- A relatively large area is required for double bins or vaults under or near the toilet pedestal.
- Systems where material is shovelled from the active bin to a curing bin or removed from a net collection system increase risk from exposure to waste.

C- 4.1.4 RISKS TO AVOID

If a flush toilet is used too much water could leach nutrients and composting organisms out of the chamber.

C- 4.1.5 PROCESS CHALLENGES AND SOLUTIONS

Flies can be a problem if vents, hatches, or toilet seat openings are not effectively sealed or if the compost pile gets too wet. Ensure that all openings are effectively sealed. Specify adding bulking agent, soil, or compost over the top of the compost pile if needed to control flies and moisture.

As thermophilic stage composting may not be achieved, composting processor size should allow for a long curing period to provide adequate stabilization and sanitizing.

C- 4.2 Proprietary double chamber prefabricated units

The 'Sirdo Seco' toilet system, made in Mexico, and the NatSol system, made in the UK, are examples of this type of composting toilet system. The NatSol system includes urine diversion in the pedestal design.

http://www.sirdo.com.mx/Anexos/PLANNING%20FOR%20RECYCLING.htm

http://natsol.co.uk/

C- 4.2.1 SPECIFICATION NOTES

Typical features and specifications include:

- Double bin
- Prefab glass reinforced cement, poly or fiberglass units with a moveable pedestal or a diverting flap in the pedestal to direct the excreta to the active bin
- Sloped floor
- Collection area sits under the pedestal with the majority of the bins sticking out from under the building.
- Sited so that the top mounted chamber hatches face the sun in order to use solar heat for processing. Hatch lids are dark painted aluminum.
- Passive venting

C- 4.3 Sizing

Approximate chamber size (each side) is 1.2 m^3 for the Sirdo Seco system. NatSol systems are available in various sizes, the standard unit is sized for up to 6 persons full time use.

C- 4.3.1 PROS AND CONS

As for open source double chamber systems, with the following special considerations.

Pros:

Solar heating (Sirdo Seco) helps with evaporation and moisture control, and may keep temperatures higher during curing.

Urine diversion (NatSol) improves process and is particularly important for public use sites.

Cons:

- Maintenance access hatches situated on top of the bins make it ergonomically awkward to remove compost.
- Directional flap in pedestal chute (Sirdo Seco) could accumulate excreta.
- Significant depth (height) is needed below the pedestal for vault construction, in some cases a sloping site is needed.

C- 4.4 Moveable bin container composting systems (open source and proprietary)

Moveable bins or containers are used together with a composting toilet pedestal as a combined collection container and composting processor. When bin one is close to full, it is moved to a designated composting and curing area and is replaced with an empty one under the toilet.

In some cases a container is used for collection and initial composting, and is then emptied to another container or pile for further composting or curing.

Where very small bins are used and emptied to a separate processing pile or container, this is considered to be the collection component of a commode system, see Section C- 4.6 below.

An example of an open source wheeled bin composting toilet system is available online at:

http://www.milkwood.net/2011/04/18/compost-toilet-specifics-the-bins/ with a discussion of bin moving at

http://www.milkwood.net/2011/11/25/wheelie-bin-trailers-for-humanure/

Other examples are available at

http://permaculturenews.org/2014/07/30/composting-toilets-made-wheelie-bins/ and at

http://www.livelearn.org/sites/default/files/docs/PacWASHCleanCommunities.pdf Consider the climate when looking at sizing information in the manual.

Proprietary versions are available, including units from Separett (http://www.separett.ca) Cotuit Dry Toilets (http://cotuitdrytoilet.weebly.com/), Biolet (http://www.biolet.com/) and Full Circle (http://fullcirclecompost.org/).

C- 4.4.1 Specification notes

Typical features and specifications include:

- Properly seal the bin to the collection system or pedestal.
- Off the shelf recycling wheelie bins can be used or food grade plastic barrels, Intermediate Bulk Containers (IBCs) or other watertight containers may be adapted by putting them on platforms with castors.
- Larger bins or Intermediate Bulk Containers can be moved by forklift, for public use sites or larger residential use sites.
- Larger bins on wheels can be left longer to fill depending on volume of bin and number of users.
- Bins must be drained to take leachate for collection and treatment. Specify connections to avoid spills and leakage when moving a bin.
- A number of medium sized bins can be specified to allow for stages of curing to be taking place in successive bins and allow for the addition of sanitizing agents in the final bin cycle or for management of a thermophilic step.
- Placing a grate or screen above the floor of the bin improves drainage and oxygen availability. Fishing net may also be used for this purpose.
- Build in ventilation near the bottom of the bin but above the leachate drain. High level vent needs to be provided individually (per bin) or to be specified with disconnects to allow moving and re connection to a vent.
- Allow for sludge accumulation by having the leachate drain slightly higher than the floor of the bin.

- Always start a new bin with an inoculated starter bed on the bottom.

C- 4.4.2 SIZING

Plastic bins on wheels are commonly used, in a size of 120 to 400 L. However, other sizes are used, including IBCs (500 to 1200 L, with 1000 L being a common size).

One person will fill a 200 litre bin with a floor grate and a leachate drain in about 200 days at 20 C compost temperature with moderate bulking agent use. For a family of 4, 4 of 360 litre wheelie bins would suffice in rotation with about a 3 month cycle of moving the bins (assuming a thermophilic step is reached).

The larger and fuller the bin the harder it is to move. Ensure it is practical and safe to move the filled containers.

C- 4.4.3 PROS AND CONS

Pros:

- Simple system
- Bins can be sized flexibly to accommodate to available area beneath or adjacent to the toilet pedestal.
- Moveable bins can take up a smaller area under the pedestal compared to a double chamber and less construction is required.
- If added capacity is needed, or a longer processing time is needed, additional bins can be put into service.
- Wheeled bins are relatively easy to move to an area removed from the building.
- Fresh excreta does not have to be handled.
- The batch system offers more opportunities for pathogen reduction. Sanitation or pH adjustment could take place in one or more of the bins.
- Heating elements with thermostatic heads (electric rods) could be easily used to create thermophilic conditions in the chosen chamber.

Cons:

- The smaller the batch size, the more frequently maintenance is required.
- A suitable location is needed for the bins or containers, with access to leachate drainage and with either dedicated or common venting system.
- When used as a collection system, container collection increases the chance of contact with fresh feces.

C- 4.4.4 RISKS TO AVOID

Do not overload bins so as to make them overly awkward to move. If moving to a remote spot on the property make sure there is a surface adequate for easy wheeling.

Do not overload to the point that material spills out when tipping the bins into wheeling position or when moving them across uneven ground.

Ensure sealing is maintained at all times to reduce risk of vector access.

C- 4.5 Open source carousel container composting systems

These systems are similar to moveable bin systems, but on a fixed platform that rotates. An example is http://biorealis.com/composter/rotating/

C- 4.5.1 SPECIFICATION NOTES

Typical features and specifications include:

- A carousel platform can be built on wheels that either has fixed compartments or removable bins that sit on the rotating platform.
- For fixed compartments, access hatches are needed to allow removal of residual organic matter.
- The design must include leachate collection and evaporation or discharge plumbing. Drainage is similar to moveable bin systems.
- If the platform is water resistant then each chamber can drain to the platform, which is drained, or each chamber or bin can be drained individually with quick connect fittings.
- Venting is needed for individual containers as well as for the composting toilet pedestal.

C- 4.5.2 SIZING

This system is sized for the expected use. 4 – 8 bins or sections is the norm. The more bins and the larger the bins, the harder it will be to turn the carousel and so care must be taken in sizing and designing the system.

C- 4.5.3 PROS AND CONS

Pros and cons are similar to moveable bin systems, with the following special considerations.

Pros:

- All of the collection and maturing can take place in one contained area with one venting and leachate system.
- Fresh excreta does not have to be handled because of being isolated in the bin at the active position.
- No separate location is needed for bins.
- The multiple bins allow for peak use flexibility.

Cons:

- Capacity can only be increased to the total container capacity of the unit; further increase is only possible by secondary composting at a separate location.
- The carousel can become unbalanced if it is over weighted to one side and so become awkward to turn.
- Castors can break down over time and will have to be replaced at some point.
- Access to material is more difficult than with moveable bin systems.
- Temperature and process control on a per container basis is more difficult.

C- 4.6 Proprietary carousel container composting systems

Carousel models include the EcoTech Carousel and the Rota-Loo.

C- 4.6.1 SPECIFICATION NOTES

Typical features and specifications include:

- A cylindrical outer tank, in some cases holding a slightly smaller inner tank.
- With a number of bins or compartments situated on a carousel that the maintenance provider rotates when the active bin is full.
- Drainage in the bottom of each bin, which drains to the floor of the carousel from where the liquids are evaporated or drained off.
- When the active bin is full and the carousel rotated then the most stabilized and cured bin is situated at the access panel to be emptied.
- Compartment architecture can vary with manufacturer to be either removable bins or fixed in place dividers.
- Optional heaters
- Rota-loo offers a larger unit suitable for public use sites which is typically used with an Ecos Soltran building to incorporate solar leachate evaporation and processor heating.

C- 4.6.2 SIZING

Size varies, and optionally the number of compartments, to adjust for volume of use. Residential units are available sized for 4 people recreational cottage use to 8 people full time residential.

Units are typically approximately 1 m. high and 1.2 m in diameter, depending on model.

C- 4.6.3 PROS AND CONS

As for open source carousel systems, with the following special considerations.

Pros:

- Reduction to 2/3 of original volume claimed under favorable conditions.
- In use since 1973.

Cons:

- Attention needs to be paid to when carousel needs to be rotated based on active bin accumulation.
- Carousel can become imbalanced and awkward to move.
- Access hatches on some systems sized at less than optimally for removing compost.

C- 4.7 Separate open container pile or bin batch composting processors, commode batch system

In this approach, collection is by small containers or by bins which are then conveyed to a separate composting processor. At that location the containers are emptied onto the pile or into the separate bin for composting. Cover material is added after each addition.

A common version of this approach is the humanure system, which uses an open container pile for compost processing. The *Humanure Handbook* is available at: http://humanurehandbook.com/manual.html

Mixing may be used during composting, and a thermophilic step is usually specified.

Procedures for open container systems vary, but a standard approach adopted by the OMRR for bin composting with time at temperature can be summarized as:

- Fill a bin following guidelines in CCME Technical documents for composting (C/N, moisture, porosity, etc.).
- Close and cover.
- The intention is for all parts of the pile to heat to >55C.
  - This can be assured by recording 3 days of 55C between pile turnings. There needs to be 5 turnings with before each turning 3 days of 55C temperatures. When turning the pile sides, bottom, and top need to be turned into the middle. Temperature is taken from the middle of the pile with a thermometer.

C- 4.7.1 SPECIFICATION NOTES

Typical features and specifications include:

- A pedestal/seat where deposits of urine, feces, excreta, toilet paper and covering/bulking agents are deposited into collection bins.
- The cabinet housing the collection receptacles is vented with a fan.
- Urine is collected with the feces and toilet paper.
- As bins fill, they are removed and replaced with an empty collection bin.
- Servicing schedules on replacing the receptacles is performed as needed (servicing cycles are flexible).
- Full receptacles are then deposited into the compost processing pile.
- Ideally suited for residential use, and public facilities with onsite attendants, or attendants that service the facilities daily.
- Small, easily manageable bins are used for collection and then transported to composting processor.
- Material added to the pile is covered by cover material.
- Addition of material to the pile and maintenance of cover material:
  - Specify cover material that is not a vector attractant, e.g. mature compost, green waste. Moist material will absorb and treat odor better.
  - Scrape back cover material prior to placing commode container or bin contents on active pile
  - After addition, clean container (rinse water may be added to pile, do not discharge to surface of ground) and replace specified cover material to a minimum 15 cm depth.
  - Do not leave fresh excreta or collected waste exposed to vector contact

- After the pile is completed and is composting and curing, another pile is started.

C- 4.7.2 SIZING

C- 4.7.2.1 Collection sizing

Sizing is directly related to service cycles, and service cycles directly related to adjusting for peak periods of use.

Generally bins are not sized any larger than can be easily and safely handled by one person (80 - 90 litres) wheeled bins (ideal for public sites), or smaller bins of 20 litres (ideal for residential systems).

Flexibility of servicing means that design of system is not related to peak usage as much as being able to service.

Recommendation for public sites is that a bin should hold a minimum of two days collections during peak usage periods.

For residential systems minimum capacity is less of an issue due to the ease of changing receptacles. It is more convenient if the cabinet that houses the receptacles houses two collection bins that can be swapped quickly.

C- 4.7.2.2 Processor sizing

The concept is to have two stage process, a thermophilic stage and a maturing stage. Two or more piles may be used. Two and three pile systems are suited to residential use, a four pile system is used for multiple toilets. The following examples are based on thermophilic composting followed by a 12 month minimum curing time.

Two Pile System:

- A compost pile receives the deposits from the collection bins, receiving regular additions for a period of one year.
- After collection of materials for a year, this pile would reach thermophilic temperatures throughout the pile. The pile would then sit and mature over another year.
- During this time, a second pile receives materials, and the cycle continues.
- A system with compost bins 1.5 m X 1.5 m x 1.5 m could serve a household of six people.

Three Pile System:

- A compost pile receives the deposits from the collection bins, receiving regular additions for a period of one year.
- The second pile is a maturing pile, which is left for 6 months, at which time it is turned over into the third pile, in essence allowing for the turning of the compost halfway through its maturation cycle.
- Third pile matures for six months before being discharged.

Four Pile System:

- One bin is added to for 6 months, then the next bin is added to for six months, then the third bin, and then a fourth bin.
- Once the fourth bin has received its 6 month collection, all materials in the first pile will have composted and cured for a minimum of 18 months and this pile is then discharged.

C- 4.7.3 PROS AND CONS

Pros:

- Simple system.

- Small area and limited height needed for toilet pedestal and collection system.
- Low cost.
- No mechanical equipment (except the ventilation fan).
- Flexible size, with maximum size controlled primarily by the size of collection containers and desired frequency of maintenance.

Cons:

- Service cycle is frequent.
- Not suitable for remote public use sites due to service interval.
- A suitable location is needed for the pile or containers, with access to leachate drainage.
- Multiple opportunities for contact with excreta by maintenance provider or operator.

C- 4.7.4 RISKS TO AVOID

Rainfall may add excessive amount of water to an open pile or container, resulting in leaching and reduced oxygen transfer. Roofing is recommended by the Manual.

Avoid storage of full containers in the sun.

Vector access control requires care with open pile systems.

C- 4.7.5 PROCESS CHALLENGES AND SOLUTIONS

Public use systems need to have frequent service cycles, therefore it is necessary to find a service provider willing to collect and process materials in periods of high peak use.

Systems designed for use in public facilities need to trash receptacles onsite for the disposal of garbage, so the "toilet" does not become a trash receptacle. The standards of the Manual include specifying trash receptacles as part of the design.

Public use systems require simple instructions with directions, "do's and don'ts"

C- 5 CONTINUOUS PROCESS COMPOSTING TOILET SYSTEMS

C- 5.1 Single chamber, sloping floor continuous process composting toilets

C- 5.1.1 OPEN SOURCE CHAMBERED CONTINUOUS PROCESS COMPOSTING TOILETS

Typical open source continuous process composting toilets use an inclined floor chamber design. One large chamber receives excreta and processes the material, typically through a mouldering process, with residual organic matter removed at the low end of the chamber.

Fresh material falls in from above and collects on top of the pile that slowly moves downward and gradually horizontally, being directed by a sloped floor towards a clean out hatch.

One example of a Clivus Minimus system is available at:

https://naturedesignsjohnfranci.files.wordpress.com/2014/03/compost-toilet-minimusctandspecs1.pdf

C- 5.1.1.1 Specification notes

Typical features and specifications include:

- Proper moisture content ideally 45 to 70%, water spray (manual or automatic) may be used to add moisture.
- Internal (heap) temperature of 40 to 50 °C (achieved by proper chamber dimensioning).
- Food scraps may be included and in some cases a garburator is used to grind wastes prior to addition.

C- 5.1.1.2 Sizing

The maximum number of users depends on factors such as temperature, humidity, amount and type of food waste added, proportion of urine to feces (particularly for public use sites), and volume of the receptacle. In general, a volume of 2 m^3 will serve 4 people using the system year round.

It may take several years until a household has to take out the residual organic matter for the first time. After that they may have to remove it once a year.

C- 5.1.1.3 Pros and cons

Pros:

- All organic materials including meat and bones can be processed.
- Compost mass reduced to about 10% of original mass under favorable conditions.
    - The amount of partially processed residual organic matter produced varies from 10 to 30 litres per person per year.

Cons:

- In practice, optimal conditions are difficult to maintain. As a result, the output product is often not stabilized and sanitized.
- Typically does not reach thermophilic temperatures.
- Not practical to increase capacity, and usage beyond the design capacity will result in poor composting performance.
- If fruit and vegetables are composted there is an increased probability of attracting fruit flies if the compost is not managed properly or ingress/egress of vectors is not prevented.

- The slanted floor does not always provide movement of the compost mass, which then requires manual manipulation of the mass to move it towards the removing hatch.
- Large chamber may be hard to incorporate into building design
- Continuous processor results in liquids migrating through the pile and re-inoculating stabilized material at bottom with new pathogens.
- Liquid accumulation needs to be maintained by pumping or draining away.

C- 5.1.1.4 Process challenges and solutions

Composting material tends to stall in its movement on the inclined plane. When specifying, keep the slope steep, slippery, and short. Make this slope accessible with a shovel or rake from the compost removal hatch.

By reducing the total volume of the chamber, less compaction is likely, and so pile movement is easier, and access is improved. Residuals removal will increase to approximately twice a year instead of once. This can be an advantage as the partially stabilized material can be removed for curing and will not be re-inoculated from pathogens migrating from the fresh material on top.

A further advantage of reduced compaction is improved oxygen transfer for the composting process.

C- 5.1.2 PROPRIETARY SLOPED FLOOR CONTINUOUS PROCESS COMPOSTING TOILETS

Clivus Multrum (http://www.clivusmultrum.com/) and CTS (Composting Toilet Systems Inc.) (http://www.comtoilet.com/) make sloped floor chamber systems.

Process and general specification is as for open source sloped floor chamber systems.

C- 5.1.2.1 Specification notes

Typical features and specifications (beyond those of open source systems) include:

- Fiberglass chamber unit.
- May include a leachate storage tank.
- An automatic moistening system allows for an ideal moisture content (45 to 70%).
- Micro-flush or foam-flush toilets are also available for these composters.
- Worms are may be used.
- Continuously running vent fan draws air through toilet seat.

C- 5.1.2.2 Sizing

In most cases a volume of 2 cu. m. will serve 4 – 5 people year round. Many sizing options available, including systems suitable for large public use sites.

C- 5.1.2.3 Pros and cons

Pros and cons are similar to open source sloped floor chamber systems. Gel coated fiberglass chambers have the advantage of being low friction, which improves movement of material through the unit. Some units are CSA/NSF certified.

C- 5.2 Proprietary vertical continuous process composting toilet

Phoenix brand made by Advanced Composting Systems (http://www.compostingtoilet.com/), single chamber vertical flow process.

C- 5.2.1 SPECIFICATION NOTES

Typical features and specifications include:

- Micro-flush or vacuum toilets can be used with the system.
- Leachate drains to a holding area for evaporation and then to a tank (not included) for treatment or for re-circulating through process.
- Feature included for spraying leachate over the top of the pile for moisturizing and inoculation of composting microorganisms.
- Tines on shaft can be rotated manually for mixing of compost and improving aeration.
- Forced air fan for evaporation and ventilation.
- Side vents allow for aeration.
- Advanced Composting Systems recommends adding one to two gallons of bulking additive through the toilet or upper access door for every 100 uses.

C- 5.2.2 SIZING

For an average family Advanced Composting Systems indicate that a Phoenix operating normally will result in approximately 0.34 m^3 residual organic matter annually, based on a claimed 90% volume reduction.

Three residential models are available, 1.35 to 2.13 m in height depending on model. Larger models suitable for public use sites are also available.

C- 5.2.3 PROS AND CONS

Pros:

- Long period of time before having to remove initial compost.
- Some units have been CSA certified.

Cons:

- Height of chamber can be hard to incorporate into building design.
- Rotating tines can at times merely create channels in composting mass rather than actually mixing.
- Opportunities for the rotating tines to get stuck and for the grate to clog.
- Continuous processor results in liquids migrating through the pile and re-inoculating stabilized material at bottom with new pathogens.

C- 5.3 Proprietary self-contained chambered continuous process toilets

These systems include: Air Head (http://airheadtoilet.com/), Biolet (Biolet USA) (http://www.biolet.com/), Envriolet and Santerra Green (Sancor Industries) (http://www.sancor.ca/), MullToa (EcoEthic Canada) (http://www.ecoethic.ca/), Nature's Head (CTS) (http://natureshead.net/), C-Head and BoonJon (http://www.c-head.com/) and Sun-Mar (Sun-Mar Corp) (https://www.sun-mar.com/).

This Section is related to the self-contained chambered continuous process units from these manufacturers. Sancor also offers commercial units and Sun-Mar offers central units (using a similar technology to their self-contained units).

Biolet also makes a small, non-electric, batch system, the Biolet BTS 33, which is based on the batch bin composting approach.

C- 5.3.1 SPECIFICATION NOTES

Typical features and specifications include:

- Mostly sized for cottage application but some manufacturers specify their larger capacity models for year round residential use. Some models intended for RV or boat use.
- Some models offer urine separation, with urine collection container.
- Many have fan assisted venting.
- 12 V DC and 120 V AC models available.
- Most of these self-contained models sit on the floor where the toilet pedestal would normally be and have a toilet seat directly on top of the processor.
- Excreta, (feces, urine, and toilet paper), drop directly into the processing chamber.
- Finished material drops into a drawer at the bottom of the unit and when the drawer is full it is removed manually to be taken outside where it will be further processed or disposed of offsite.
- Some models have a heating element under the leachate collection tray in the bottom. The heat evaporates the bulk of the urine and leachate as well as raising the temperature to facilitate the composting process.
- Peak loading will generate more liquid than can be evaporated and this is carried by an overflow drain to the outside for treatment. As with all composting toilet systems, follow the standards of the Manual and the SPM for leachate treatment and dispersal.
- Most of the models have some form of mechanical mixing. Some have metal arms that are manipulated manually and one has a drum that is manually rotated. Electric mixing is also provided by some models.
- Bulking agent is added on a regular basis.
- Some have slightly larger central models that are located beneath the pedestal floor or nearby, connected to a micro-flush or vacuum toilet. These may have more complex processing stages.

C- 5.3.2 SIZING

The manufacturers have a number of models, rated for a specified number of users and type of use or for a specified number of uses per cycle.

The units are mostly designed to fit into the space that would usually be used by a toilet pedestal but slightly wider.

Some are slightly higher than a standard toilet but have a small step in front that makes for a comfortable sit.

Area must be provided for a container of bulking agent.

C- 5.3.3 PROS AND CONS

Pros:

- All units come with installation and maintenance guidance manuals.
- Most manufacturers provide on phone guidance with operation and/or repairs when required.
- Replacement parts, inoculants, and bulking agents are available from most manufacturers.
- Small size means they can be accommodated easily within most standard houses or cottages without requiring extensive renovation or construction.
- These units are more economical than larger chamber systems that must be installed in a basement or under a building.
- Some units are CSA/NSF certified.

Cons:

- The smaller compartment size requires more frequent maintenance and residuals removal.
- Residuals removal takes place inside of the dwelling.
- Heating element and vent fan create a higher energy demand than larger, more passive units.
- Sludge build up in the evaporation tray can block the overflow, which then causes a buildup of leachate and consequent overflow to the room. Sludge must be removed manually.
- The fans may be smaller and hence louder than the inline fans of the larger composting units.
- Heating elements burn out eventually, which requires emptying and disassembly of the unit and replacing the element.
- High temperatures can cause the compost to dry out enough to be below moisture levels required for composting and so dehydration can occur rather than composting, this may also result in hardened material which is difficult to remove from the unit.
- Power is needed. If the power goes out then the fan and heater stop working, which may result in odours in the dwelling and less evaporation of leachate.
- Continuous processor results in liquids migrating through the pile and re-inoculating stabilized material at bottom with new pathogens.

C- 5.3.4 RISKS TO AVOID

For seasonal recreation dwellings recommend that the unit is to be emptied before leaving at the end of the season. This will help to avoid complete drying of excreta in the unit, which can lead to cementation and consequent problems with having to remove dried material manually at next season’s start up.

If contents can freeze, provide instruction and signage to prevent activation of the mechanical stirring mechanisms prior to thawing.

C- 5.4 Process challenges and solutions

If owners are sensitive to the fan volume, replace fans with a custom installed inline fan that runs full time but at lower noise levels.

Choose the model size conservatively, preferably select a model one size larger than recommended for a specified number of people, particularly for year round continuous use.

C- 5.5 Flow-through vertical vermicomposting chambers

The flow-through concept is a single chamber, continuous vermicomposting process. This was developed by Dr. Clive Edwards and colleagues in England in the 1980s. This is an open source technology.

Vermicomposting units using this approach are manufactured by Worm WigWam, these processors may be added to a composting toilet process to provide a vermicomposting step.

- http://www.wormwigwam.com/worm-wig-wam-vermicomposting-bin/

C- 5.5.1 Specification Notes

Typical features and specifications include:

- A worm bin approximately one cubic meter in volume or less is situated centrally under the toilet chute.
- The bin is elevated above the floor of the chamber approximately 30 centimeters.
- The bottom of the bin is a grate consisting of corrosion resistant bars or mesh.
- A hydraulically controlled scraper bar is moved across the top of the bars or mesh causing the finished compost to fall to the floor of the chamber below.
- In lieu of a mechanized scraper a rake can be used manually to rake the underside of the pile through the bars again causing the compost to fall through the bars.
- Compost under bin is then shovelled up and removed for further curing.
- 70 -80% moisture content range is typical.
  - For optimum moisture conditions for the worms a micro spray head on a timer can be installed to moisturize the pile on a regular (2 or 3 times a week or as needed depending on humidity and temperature)
  - The fresh water spray also helps to leach urine out of the pile.
  - Without the micro spray the worms will still consume the excreta, but the spray optimizes the conditions for them.
- Bulking agent (“bedding”) is added with every faecal event to create structure and absorb liquid.
- Worm populations can be expected to double every 60 to 90 days under optimum temp. and moisture.
- The worms’ burrowing action creates channels which help with drainage and oxygen absorption.
- A drain in the floor of the chamber is used to remove leachate and urine.
- A method is specified for separating worms from the compost, for example the residuals are shaped to a cone and exposed to light, the worms go to the bottom of the cone as they move away from light.

C- 5.5.2 Sizing

In general, outputs from vermicomposting processes can vary from about 10% to 50% of the original weight of the inputs. This will vary with the nature of the inputs and the system used. The greater the proportion of high-carbon inputs to high nitrogen inputs, the greater will be the weight of final output as a proportion of input weight.

Clive Edwards has stated that a "properly managed" flow-through unit of approximately 10 m^2 surface area can process 2 to 3 tonnes per day of organic waste.

C- 5.5.3 PROS AND CONS

Pros:

- The usual C:N ratio required for effective composting is not required for vermicomposting as the worms do not require this C:N relationship to produce worm castings.
- Vermicomposting is effective in breaking down complex organic chemical compounds and achieving pathogen reduction
- Worms consume ½ to 1 times their body weight daily
- Can tolerate a pH range of 5 – 9 and a wide temperature range.
- Vermicompost, like conventional compost, provides many benefits to agricultural soil, including increased ability to retain moisture, better nutrient-holding capacity, better soil structure, and higher levels of microbial activity. A search of the literature, however, indicates that vermicompost has been shown to be superior to conventional aerobic compost in a number of areas and typically has lower ammonia levels (and higher nitrate levels).

Cons:

- Continuous vertical processing can allow pathogens to migrate down into finished castings at the bottom of the bin and so a post worm bin curing phase is required.
- High ammonia content is detrimental to, and in high enough content, toxic to, worms.

C- 5.5.4 RISKS TO AVOID

Temperatures above 35C are fatal to worms and so thermophilic temperatures are not desirable. If the pile does get mixed causing the temperatures to rise dramatically then the worms will move to the outside cooler temperatures of the pile.

Freezing temperatures can kill worms. The worms will find warmer conditions in the centre of the mass but if freezing winters are standard in the region then the bin must be in a heated space to avoid freezing.

C- 5.6 Process challenges and solutions

Anti-worm medication can impact the worms. If a person is taking worm medication they should avoid using the vermicomposting toilet.

Worms are photosensitive so the chamber should be kept dark, which will bring the worms to the surface of the pile to consume the fresh material.

C- 5.7 Proprietary horizontal vermicomposting system

Toilet Tech Solutions (http://www.toilettech.com/home.html). Typical features and specifications include:

- Urine diversion system options include a conveyor system, wiper system and a urine diverting pedestal.
  - In the conveyor system, all liquids and solids drop to an upwardly inclined conveyor belt from which the urine drains to separate collection and the fecal matter is discharged to the composting chamber. A foot pedal at the base of the pedestal activates the conveyor belt to move the solids towards discharge in the adjacent composting chamber.

- Worms are used for the composting process.
- No bulking agent is added
- The adjacent composting chamber can be designed flexibly with site requirements so that it can be behind or below.
- The composting material is moved manually with a rake, with the final pile next to the residuals removal hatch.
- The maturing piles are covered with plastic sheet or straw so as to retain moisture and to provide suitable conditions for the worms.

C- 5.7.1 SIZING

Composting bin size: 3.5 m^2 of chamber floor area for 5000 uses per year with design target of 10 to 20 year usage prior to solids removal.

C- 5.7.2 PROS AND CONS

Pros:

- Due to no bulking agent being used and effective vermicomposting, residuals volume is small.
- Effective separation of urine optimizes the environmental conditions for worms.
- Urine separation systems do not require user training.

Cons:

- Urine quality from conveyor or wiper system is more heavily contaminated than for some other diversion methods due to mixing with faeces on the conveyor belt before separation.
- Urine dispersal system needed.
- Some maintenance intervention with entry to composting chamber needed to manage process.

D Procedure checklists for composting toilet systems

The following checklists are not intended for use as is. They are intended to inspire APs to create their own custom checklists or design tables.

Design tables in a spreadsheet format are recommended, using a spreadsheet will streamline the design process and allow for easy documentation of rationale.

The Manual includes an appendix with filing documentation checklists for composting toilet and greywater systems (Appendix D-6).

D- 1 PLANNING CHECKLIST

D- 1.1 Primary purposes

- ☐ Safely and hygienically collect and contain human waste
- ☐ Manage odors and prevent vector or human access during storage
- ☐ Manage leachate and safely discharge leachate or diverted urine to a combined or greywater sewerage system
- ☐ Provide for safe and practical management of residual organic matter.

D- 1.2 Secondary purposes

Discharge method for residual organic matter:

- ☐ Off-site discharge
- ☐ On-site burial
- ☐ On-site surface discharge (professional)

Define residual organic matter performance objectives:

- ☐ Stabilized: ____
- ☐ Matured: ____
- ☐ Sanitized: ____
- ☐ Incineration:______________________________________
- ☐ Standards for the process and documentation of the process:

D- 1.3 Site evaluation and preliminary design considerations

Type of use:

- ☐ Residential Full Time
- ☐ Residential Seasonal
- ☐ Public use site
- ☐ Remote site

Site constraints for installation:

- ☐ For throne models or commode collection, available space indoors

- ☐ For combined collection and composting processors:
  - ☐ Available space for collection/processor
  - ☐ Available head room, width, and depth, below water closet floor for combined processor
  - ☐ Seasonal high water table or surface water run-off pattern
  - ☐ Access for monitoring, maintenance, compost removal
- ☐ Location for curing process container
- ☐ Ease of transport between collection and curing container/s:
- ☐ Construction required for installation of pedestal and collection/processor.
- ☐ Site and soil evaluation and documentation if on-site discharge (burial) or land application is planned.

Attach detailed drawings specifying process and discharge specific components and dimensions

D- 1.4 Design volumes

Type of use, residential:

- ☐ Residential full time use
- ☐ Number of occupants: ______________________________
- ☐ Recreational residential seasonal use
- ☐ Schedule of use: ______________________________
- ☐ Number of occupants at peak use: ______________________________

Type of use, public facility

- ☐ Estimated uses per day: ______________________________
- ☐ Year round use
- ☐ Seasonal
- ☐ Remote

Design volumes:

- ☐ SPM equivalent combined sewage daily design flow (DDF) for the site and use:
- ☐ Minimum average daily excreta volume collected by the system: ______________________________
- ☐ Average daily additive volume: ______________________________
- ☐ Total average daily collected waste volume with additives: ______________________________
- ☐ Average daily leachate and or urine volume: ______________________________
- ☐ Peaking or safety factors: ______________________________
- ☐ Predicted volume reduction in processing: ______________________________

System sizing and rationale summary:

- ☐ Collection system, collection interval: ______________________________
- ☐ Conveyance system: ______________________________
- ☐ Processor, size and number of containers: ______________________________

- ☐ Collection and treatment capacity, maximum: ________________________________

D- 1.5 System selection

Type of system:

- ☐ A proprietary unit
- ☐ A site built unit, open source documentation: ________________________________
- ☐ A system custom designed by a professional

Type of process:

- ☐ Chambered Batch
- ☐ Commode Batch
- ☐ Chambered Continuous

Type of system chosen, rationale summary: ________________________________

D- 1.5.1 PROCESS

- ☐ Conveyance
- ☐ Collection
- ☐ Processing Stages, and time for each stage: ________________________________
- ☐ Total time to maturity: ________________________________
- ☐ Lactic-acid fermentation
- ☐ Psychrophilic
- ☐ Mesophilic
- ☐ Thermophilic:, time at temperature : ________________________________
- ☐ pH adjustment
- ☐ Urea treatment
- ☐ Vermicomposting
- ☐ Fungal/Bark chip composting

Describe process constraints and how they will be addressed:

____

Identify compost maturity anticipated at time of removal from the processor and what further processing will be required:

____

For batch systems determine the number of batches planned for and residence time at specified temperature of each batch:

____

- ☐ For batch processes, provide for labeling of batches to identify time of last addition of fresh material

Specify the required temperatures for each stage of the process and how the system design will facilitate and maintain temperatures for each stage of the curing process.

____

Specify moisture requirements for each stage of the process and how this will be undertaken.

____

D- 1.6 Specifications

- ☐ Pedestal Seat
- ☐ Specify venting considerations for pedestal seat.
- ☐ Ensure that there is no possibility of user contact with excreta
- ☐ Ensure ease of cleaning
- ☐ Collection System
- ☐ Specify type of pedestal
- ☐ Urine diversion
- ☐ Non urine diversion
- ☐ Urinal
- ☐ Vacuum
- ☐ Water flush
- ☐ Foam flush
- ☐ Container
- ☐ Ventilation System, smoke test
- ☐ Sealed against moisture and vectors
- ☐ Reliability - Structural and vector access provisions to be reliable for life of the unit
- ☐ Hygiene – Ensure all hygiene has been considered for all aspects of system including user hand cleaning.
- ☐ Maintenance and Monitoring Access considerations
- ☐ Ease of maintenance
- ☐ Safety of maintenance provider
- ☐ Bulking Agent and Additives:
  - ☐ Specify type of bulking agent, if any: ______________________________
- ☐ Leachate Management
  - ☐ Drainage installed and specify fate of leachate/urine drainage
- ☐ Horizontal Separation: ______________________________
- ☐ Installation – Ensure that manufacturer or open source instructions are followed and comply with codes
- ☐ Users, Access, and, Safety
  - ☐ Ensure that all necessary signage is installed in a neat, legible, and appropriate location.

    - Ensure safe and hygienic use of facility is provided for.
    - Trash Receptacle and Signage

D- 1.7 Residual organic matter

- Off-site discharge
    - Identify options and locations of receiving facilities.
- On-site burial
- Process, meeting standards of the Manual, summarize rationale: ____
- Performance objectives for the discharge method: ____
- Plan for burial, rationale for selection, sizing and siting of the system: ____
- Specifications and drawings of the burial system
- Specify staking and signage to identify burial area
- Specified solutions used to meet standards for residual organic matter and burial: ____
- On-site surface discharge
    - Professional only. Attach site and project specific documentation.

D- 1.8 Filing

- Approval from local government building inspection officials for substitution of a composting toilet for a water closet, where applicable
- Owner:
    - Inform the owner of the operational and procedural needs for the chosen system and process before filing.
    - Confirm that the owner will undertake to properly manage the system before filing.
    - Ensure that the owner is informed of full life cycle costs of the system before filing.
- File the composting toilet system under the SSR, following standards and guidelines for filing documents

D- 2 OPERATION AND MAINTENANCE

- Defined objectives of the composting toilet system: ____
- Specific outcomes: ____________________________________
- Description of system including all required parameters and related monitoring requirements.
- During maintenance and monitoring, document system performance related to the original performance specifications.
- Create check list specific to the needs of the system for the maintenance provider to follow and on which to provide documentation.
- Measures to take if system does not meet requirements.
- Management procedures for residual organic matter.

- For on-site burial, retain documentation for each batch buried to meet the standards of the Manual.
- Maintenance intervals with rationale of intervals to process requirements
- Owner has been informed of:
  - Operation needs
  - Construction as well as life cycle costs
  - Owner has agreed in writing to undertake the stated operational needs and operate the system properly.
- Servicing frequency
- Record modifications or alterations made to system to maintain process.
- Safety and hygiene precautions

E Wastewater constituents and application of greywater to soils

E- 1 GENERAL CHARACTERISTICS OF SOURCE SEPARATED WASTEWATER STREAMS

Table E- 1 summarizes typical pollutants found in greywater streams and attendant risks.

Table E- 1. Source separated wastewater streams and key contaminants

CATEGORY	KEY POLLUTANTS	KEY RISK FACTORS
Very light greywater	Soap, shampoo, detergents, preservatives, hair dyes, toothpaste, other personal care products, hair, phlegm, soil, sediments, organic matter, fecal/urine/blood contamination, cleaning agents.	Surfactants, Pathogens, personal care products and cleaning products.
Laundry	Hair, soil, detergents, washing powders, soap, salt, softeners, bleach, dyes, cleaning agents, preservatives, oil and grease, personal care products, perfumes, fecal/urine contamination, lint and fragments of cloth, organic materials, disposal of unwanted substances (laundry tub), high sodium and alkalinity.	Surfactants, Sodium, Boron, Alkalinity, Pathogens, personal care products and cleaning products, lint. Moderate BOD.
Dark greywater	Food wastes, oils and greases, salt, flavors, preservatives, nutrients, soil, food particles, biocide residues, detergents, soaps, and other cleaning agents, high sodium and alkalinity.	Surfactants, Sodium, Boron, Alkalinity, Pathogens (including from food), cleaning products, oil and grease, high BOD, organic chemicals from food washing, high water temperature.
Urine	Ammonia, phosphorous, high sodium, risk of contamination by other excreta, complex organics including hormones and pharmaceuticals.	Nutrients, pathogens, high ammonia content.
Blackwater	Fecal matter and urine, complex organics.	Pathogens, nutrients, cold water temperature.

From these general characteristics it can be seen that types of source separated wastewater have different characteristics and are suited to different methods of treatment and different uses.

E- 2 SOURCE SEPARATED RESIDENTIAL WASTEWATER FLOW VOLUMES

The standards of the Manual provide a method for calculation of daily design flows based on a proportion of combined sewage flow estimated following the SPM. As a background this Section provides typical (median) design values for residential source separated wastewater stream average daily flows. Table E- 2 summarizes median average daily flows for source separated wastewater streams, these values are consistent with the average flows used for development of the SPM design flows.

Flow variation for source separated wastewater streams is generally greater, both by day and by time of day, than for combined sewage. In some cases peaking factors can be considerably higher.

Table E- 2. Average daily flows for source separated streams

SOURCE SEPARATED STREAM	ADF (L/C/DAY)
Combined sewage	171
Urine	1.5
Leachate (without flush or wash down water)	1.5
Blackwater	51
Brownwater	50
Water separated from blackwater	50
Combined greywater	120
Dark greywater	12
Light greywater	108
Laundry greywater	55

E- 3 NON-PLUMBED GREYWATER COLLECTION SYSTEMS

For sites where the building is not plumbed, greywater may be collected using a container system. Containers should be completely emptied to the septic tank or (for mulch basin systems) to the sub-irrigation system daily.

To facilitate emptying a fixed funnel or sink may be provided. If connected to a septic tank this should have a trap and downstream high level vent to allow venting of the septic tank. A cover or screen is necessary to restrict vector access. In all cases piping should be laid to empty completely between doses of greywater.

To reduce health risk containers and any discharge point are to be labeled, however it is also recommended that access to the containers and discharge point be restricted to prevent access by children, pets or vector organisms.

E- 4 GREYWATER APPLICATION TO SOILS

Greywater can be safely applied to soil treatment and dispersal systems, but care is needed to consider the potential risks based on the special characteristics of greywater. When considering how to address risks, it is recommended that the AP follow a multi barrier approach.

E- 4.1.1 HIGH SUSPENDED AND TOTAL SOLIDS CONCENTRATION

Where direct application of greywater is used, a fine mesh strainer installed at source is recommended. For example, hair strainers on shower or bath drains. This is particularly important if source control does not adequately limit total solids—otherwise infiltrative surface plugging and obstruction of the distribution system can result.

This is also the reason that when specifying direct application systems those with easy access for maintenance (including for cleaning the distribution system and the infiltrative surface) and open architecture that permits macrofauna access to solids will be preferred.

Where Laundry Greywater is used, synthetic fabric lint can be an issue since it will not break down in the dispersal system. Oversized effluent filters with small mesh size and or dedicated filters at the washing machine discharge are recommended.

E- 4.1.2 SODIUM, PH AND BORON

Detergents, water conditioners and soaps frequently contain high levels of Sodium and Boron and are alkaline. Sodium is a risk factor for soils with any clay content (see information on water softener discharge in the SPM). Risk of accumulation of Boron and Sodium is higher in low rainfall areas where leaching is less significant.

Alternating systems and leaching with fresh water will assist with control of accumulation. Adjustment of effluent or soil sodium absorption ratio (SAR) using Calcium and Magnesium may also assist. Selection of low Sodium and low Boron soaps and detergents is recommended; for this reason liquid detergents are preferred. See Section F- 1.3.

Greywater, particularly Laundry Greywater, can have high pH (although this is not always the case). This can be an issue for irrigation of certain plants (for example blueberries, rhododendrons), so pH testing may be important if acid loving plants are to be irrigated.

Water softener discharge is frequently high in Sodium and so extreme care should be exercised if this water is to be included with the greywater stream.

E- 4.1.3 PHOSPHOROUS

Phosphorous applied to a dispersal area may be a risk to freshwater ecosystems. It is therefore recommended that source control for greywater systems include the use of low or no phosphorous detergents. Where a septic tank is used a large proportion of the phosphorous from greywater streams is typically removed to accumulate with sludge in the tank (note that this is not the case with combined sewage flows), reducing risk.

E- 4.1.4 SURFACTANTS

Detergents and soaps leave residual ionic and anionic surfactants in the greywater stream and these may in some cases accumulate in soil, causing soils to become water repellent (hydrophobic) and reducing infiltration capacity and also lead to forcing of bypass (preferential) flow. This can work with other factors to reduce the Long Term Acceptance Rate for greywater application and increase risk of poor treatment in soil. As above, risk is higher in dry areas.

Alternating systems and leaching with fresh water will assist with control of accumulation. Where soils are already suspected of being slightly hydrophobic particular care is needed.

E- 4.1.5 OIL AND GREASE

Although oil and grease is broken down in the soil, excessive application will cause clogging and residual compounds can also contribute to soils becoming water repellent. Oil and grease are also problematic for distribution systems.

Source control is critical in the control of Oil and Grease, particularly where dark greywater is applied. Where dark greywater is to be used, at minimum a septic tank with effluent filter should be used on the kitchen stream to act as a grease interceptor. This will have the added advantage of allowing for cooling of water prior to application.

E- 4.1.6 PATHOGENS

All types of source separated wastewater, including all types of greywater, contain significant levels of pathogens. Pre-treatment does not generally reliably reduce this risk, and UV disinfection of greywater streams prior to treatment (or as the sole form of treatment) is not reliable due to suspended solids levels in the effluent. Several pathogens have been shown to multiply in stored greywater, so that regrowth of pathogens after partial disinfection is an additional risk.

Source control can assist with reducing pathogen levels. For example, when diapers, clothes, or bed linen contaminated with feces or vomit are being washed laundry greywater should be diverted to the normal septic system.

For direct application systems, avoid storing greywater for more than 12 or 24 hours to reduce breeding of bacteria in the stored greywater. Also for direct application systems it is important to specify and construct the system to allow complete drainage of components in order to avoid opportunities for biofilm growth.

Risk from pathogens should be considered in other contexts that simply contamination of soil or groundwater. Risk can be via direct contact with greywater prior to or after soil application (example inhalation of spray from a pump system, contact with broken skin when cleaning a strainer, ingestion of soil) and indirect (example vector transmission by pests or pets or by contact with garden tools used in contaminated soil).

Greywater and other source separated wastewater effluent should only be applied below the surface, and should at no time pond or rise to the surface. In addition, application should avoid saturation of the soil and forcing of bypass flows. This means that low HLR and proper distribution should be used to avoid soil saturation.

Greywater should only be applied to soils where adequate pathogen removal will occur prior to the water reaching a water table or other boundary of concern. This is why the SPM distribution, dosing vertical separation and horizontal separation standards and guidelines apply to all types of greywater systems.

Tree and bush food crops or crops which carry fruits well above soil level can be safely sub-irrigated with wastewater effluent, however this is not suitable for other food crops. In all cases, stopping greywater irrigation well before harvest is recommended.

Likewise, application in areas where humans will come into contact with effluent is not recommended (for example, shallow sub-irrigation in herbaceous borders). Consider the risk to children playing in irrigated areas.

E- 4.1.7 COMPLEX ORGANIC COMPOUNDS AND TOXINS

Termed priority pollutants, complex organic compounds and organic toxins come to residential wastewater from household products, pharmaceutical and personal care products and from the body (as a result of ingestion or produced in the body). There are a very large number of these compounds, commonly cited priotity pollutants include:

- Benzene and Polyaromatic Hydrocarbons
- Chlorinated Aliphatics
- Chlorinated Alkenes
- Chlorobenzenes
- Phenols
- Hexachlorocyclohexanes
- Pesticides and herbicides
- Organometallic compounds

- Surfactants
- Fire retardents
- Hormones
- Endocrine disrupters (xenohormones)
- Fragrances
- Caffiene

Some of these compounds occur in higher concentration in the greywater parts of the waste stream, and the risk of long term concentration in soils should be considered.

Some vegetables such as legumes have been shown to absorb and concentrate complex organic chemicals. There has not been comprehensive study on this issue but there could be risk of food contamination.

In addition to organic chemicals there is also a risk of contamination by metals, including heavy metals, from plumbing or other sources. Radionuclides used in disease treatment may also be found in source separated wastewaters.

As with other risk components, source control policies are critical to the reduction of pollution.

Some products including cleaning products and medicines will affect soil organisms, careful selection of products in the house will assist in preserving a favorable soil ecosystem.

In some cases cleaning products and soaps may damage the soil ecosystem severely, resulting in reduced soil based treatment of greywater. For this reason, selection of appropriate soaps and cleaners should be part of the educational material provided to owners as part of the maintenance plan.

For the purpose of the Manual the following basis was used when establishing source separated residential wastewater septic tank effluent loading rates:

- Removal rate in the septic tank for $cBOD_5$ 27% for light and combined greywaters and 58% for dark greywater.
- Suspended solids removed in the septic tank to similar levels to Type 1 effluent.

E- 4.1.7.1 Risk from complex organic pollutants

As greywater and urine streams contain the majority of hormone, pharmaceutical and personal care product contamination APs should consider the potential uptake of these complex organics by vegetation that is irrigated with greywater and urine. Risk is reported to be lower with irrigation of fruit or nut trees (although variable depending on species), higher for irrigation of vegetable crops and particularly for legumes.

In general the breakdown and removal of complex organics is improved with low hydraulic loading rates and increased levels of coarse woody organic matter. Where the owner is concerned about the potential impact of complex organics it may be preferable to use the wastewater for irrigation of non-food plants.

E- 4.1.8 SEASONAL URINE SYSTEMS

During long term storage of urine the urine is disinfected to a level that results in low risk from pathogens.

Urine is high in nutrients, particularly nitrogen and phosphorous. Ammonia and nitrate nitrogen have a potential to cause environmental pollution and health risk. Urine is also high in salts and application of undiluted urine at high loading rates may result in damage to plants, or to long term salt accumulation and soil damage in drier climates.

Where sodium accumulation is a critical concern, seasonal urine systems are not suitable.

During the growing season urine which is diluted and applied sub surface to the root zone of actively growing plants can provide beneficial nutrients to those plants. This leads to reduced risk from nutrients leaching to the receiving environment, particularly where aerial parts of the plants are harvested and removed from the site.

Dilution with greywater is practical, particularly where greywater is being used for seasonal irrigation. The standards specify a minimum dilution ratio (1 urine: 10 parts fresh water or greywater). A higher dilution may also be used, depending on fertigation objectives.

To determine the safe application rate for urine the AP needs to consider HLR and nutrient balance. HLR may be adjusted to a safe level by dilution of the urine to result in BOD and COD levels similar to Type 1 effluent, or by reducing HLR to result in the same mass loading to the infiltrative surface as for Type 1 effluent—while at the same time maintaining distribution uniformity.

Nutrient balance is considered by relating the urine application rate to the maximum safe nitrogen application rate for the soil and crop. Where nitrogen requirements are not calculated, as a guideline, limit application of urine to 1 square metre per person day of stored urine.

As a simple example, a lawn where grass clippings are removed may use approximately 18 g of Nitrogen per square metre over the year (primarily from March to November). Based on 11 g Nitrogen per capita day in Urine (total) and 80% urine diversion rate one person provides approximately 8.8 g/day Nitrogen in their Urine. Applied over an 8 month period this equates to approximately 2000 g Nitrogen, which could fertilize up to 117 square metres of lawn. For improved efficiency calculation should be based on soil and or plant testing, soil type, soil organic matter content and other factors.

Fertilizer application timing is important, in general fertilizer application is not useful once a crop is close to harvest and application typically stops at about ¾ of the time from sowing to harvest.

Local Ministry of Agriculture offices can provide assistance with nutrient balance calculations and fertilizer requirements. Also see the irrigation resources referenced in the Manual.

Fresh or stored urine may be added at minimum 10 parts light greywater to 1 part urine prior to discharge in a mulch basin system. Higher levels of dilution may be preferable, depending on fertigation objectives.

F Homeowner educational material on greywater systems

F- 1.1 Greywater characteristics and variability

Greywater and source separated wastewater flows and quality vary widely from household to household, and it is important to consider how your use of your greywater system may affect performance of the system.

A greywater system requires more owner involvement and attention than a sewer connection or a combined sewage on-site sewerage system. This is particularly the case when a seasonal diversion system with irrigation use of the greywater is installed.

This Section provides information on how to manage risks related to greywater systems.

F- 1.2 Health and environmental risk

To reduce health risk, follow the following guidelines:

- Ensure that the greywater system is operated and maintained in accordance with the system maintenance plan.
- Retain a certified Maintenance Provider to undertake system maintenance.
- If an individual in the household is ill or when washing diapers, divert greywater to the all season combined sewerage or greywater system.
- Maintain the marking and labeling of all greywater diversion and distribution components.
- Do not cross connect your greywater system to a potable water system.
- Ensure that diverted urine is stored for a minimum of 6 months before being used for fertigation, or divert urine to combine with greywater.
- Only disperse or irrigate with greywater subsurface, maintaining a minimum mulch or soil cover of 15 cm over all dispersal components and over wet soil or mulch material.
- Do not allow greywater to come into direct contact with food.
- Do not share greywater with other households, or use greywater from other households.
- If cleaning greywater components, avoid contact with aerosols of greywater or biofilm and disinfect tools and surfaces after use. Wear disposable gloves and goggles.
- Do not clean effluent filters on the surface of the ground, clean them into the septic tank.
- Prevent children and others from coming into contact with greywater irrigated soil, and disinfect tools used for maintenance of greywater mulch basins or soil systems.
- Prevent pets from digging in greywater irrigated mulch or soil.

To reduce risk of negative impact on the environment and improve system lifespan:

- Follow source control recommendations in the Manual and your system maintenance plan.
- Allow for seasonal leaching of irrigated areas or, for very dry areas, do not irrigate continuously with greywater.
- Do not over irrigate with greywater, this will lead to soil saturation and reduce soil based treatment of greywater leading to potential health and environmental risk as well as to reduced system life.
- Do not irrigate with greywater when irrigation is not necessary, for example when it is raining.

- If you are concerned about nutrients (nitrogen and phosphorous) impacting fresh or marine water bodies irrigate plants that will be harvested, this can include fuel wood crops.
- Closely monitor greywater dispersal system performance, including the response of the soil and plants to the applied greywater. Contact an Authorized Person for advice if issues are observed.

F- 1.3 Source control and selection of cleaning and personal care products

To reduce the risk of negative impact on the environment, and to help with proper operation of the greywater system follow the following guidelines:

- Reduce the amount of particulates in your greywater stream, including hair, lint, food particles and grit.
- Use screens on sink drains.
- Use a lint filter on the washing machine discharge.
- Wipe plates before washing to remove food and grease.
- Do not put food or beverages down the drain.
- Use liquid soaps and detergents and check ingredients for environmental toxicity.
- Do not use drain cleaners
- Do not put toxic substances, paints, oils, waste chemicals, pharmaceuticals etc. down the drain and do not use greywater from washing clothes or rags contaminated with paint, grease, oil etc.

Cleaning and personal care products can contain compounds that will damage your greywater system and which may cause negative health or environmental impact when the greywater is dispersed or used for irrigation. With some compounds there is a risk that plants will take up and concentrate the complex organic contaminants, so if you are concerned about this and cannot remove the contaminants from the greywater source do not use the greywater to irrigate crops which will be eaten. Sodium and Boron and compounds containing these elements may be an issue, particularly where climate is dry. Be aware of the compounds used in your products, and select products avoiding the following:

- Detergents or soaps with:
  - Sodium salts (often used as bulking agents—fillers—in powdered detergents, liquid detergents may be preferable).
  - Peroxygen or sodium perborate, sodium trypochlorite, sodium tripolyphosphates (STPP), phosphorous, phosphates, polyphosphates, petroleum distillate, alkylbenzene, sodium trypochlorate
  - Anti-microbials such as Triclosan
  - LAS surfactants (commonly found in powdered detergent and liquid dish soap)
- Chlorine bleach.
- Fabric softeners and whiteners.
- Products containing Triclosan or other anti-microbial compounds, including anti-microbial preservatives such as parabens.
- Products containing nonlyphenol, NPE or octylphenol (surfactants)
- Products containing fragrances, example hexyl cinnamic aldehyde

"Organic" or "natural" products may also contain complex organics that can impact health and the environment.

It may be helpful to make up printed labels to remind users of source control requirements, for example a list of allowed detergents posted next to the washing machine.

Information on personal care and cleaning products can be found at:

- Environmental Working Group http://www.ewg.org/consumer-guides
- Safe Cosmetics http://safecosmetics.org
- Soap and detergent information http://www.harvestingrainwater.com/greywater-harvesting/greywater-compatible-soaps-and-detergents/
- L. R. PI, Y. Qian, M. Criswell, M. Stromberger, and S. Klein, "Long-Term Effects of Landscape Irrigation Using Household Graywater–Literature Review and Synthesis.", 2006. Available from WERF at http://www.werf.org/