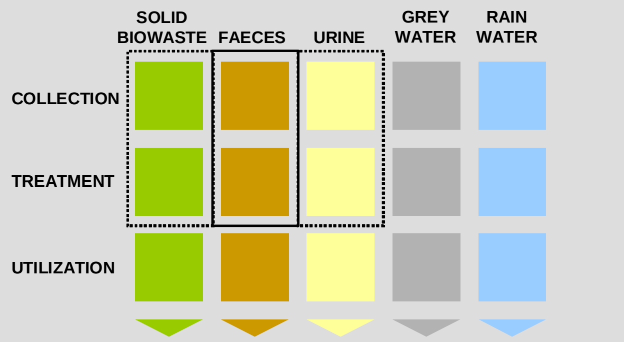
Basic overview of composting toilets (with or without urine diversion)

Draft



Preface and acknowledgements

Dear Reader,

This document is a revised version of four separate documents (technical datasheets) on “composting toilets” which were published on the GTZ ecosan website in 2005. Authors of those four documents were Christine Werner, Aileen Huelgas, Florian Klingel, Patrick Bracken (in 2005 they were all working for the GTZ ecosan team). This revision has become necessary to include new findings from research and full-scale installations.

The update was written by Wolfgang Berger and reviewed by Patrick Bracken. If you spot omissions or errors, please e-mail us your feedback at ecosan@gtz.de.

We hope that you find this publication useful for your own ecosan projects and dissemination activities.

Kind regards,

Dr. Elisabeth von Münch

Leader of GTZ program „Sustainable sanitation – ecosan“
(program carried out on behalf of BMZ ministry)

Author: Wolfgang Berger
Edited by: Patrick Bracken, Dr. Elisabeth von Münch

Please send feedback and comments to the e-mail address given below. We look forward to hearing from you.

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

ecosan program

Dag-Hammarskjöld-Weg 1-5
65760 Eschborn, Germany
T +49 6196 79-4220
F +49 6196 79-7458
E **ecosan@gtz.de**
I www.gtz.de/ecosan

This docume nt is available from:
http://www.gtz.de/en/themen/umwelt-infrastruktur/wasser/9397.htm

partner of
sustainable sanitation alliance

Contents

List of tables:

List of figures:

1 Overview

1.1 General description

Composting toilets are dry toilets, meaning that they operate without the need for flushing water. They can therefore be used independently of connections to water supplies and sewers and can thus provide a safe and hygienic sanitation alternative for areas without sanitation infrastructure. Composting toilets can considerably reduce household water consumption and the costs of wastewater treatment for blackwater and are therefore also used in sewered areas.

By separating faeces and urine from wastewater, plant nutrients and organic matter can be recycled through composting and the remaining household wastewater can be treated more easily. In this regard, composting toilets work as local pre-treatment systems retaining substances which may be harmful to the environment.

The composting process involves the degradation of organic matter mainly by thermophilic aerobic bacteria. Under optimal conditions the bacteria can produce temperatures within the composting heap in excess of 50℃ and thus can provide a fast and substantial pathogen reduction. Due to its complexity, however, the composting process may prove difficult to manage within the composting vault. Experience from temperate regions has shown that it is difficult to reach temperatures above 40° C in the composting vault and the normal operating temperature range is often mesophilic or ambient.

Pathogen content is nevertheless reduced in a composting toilet, but complete pathogen destruction can not be guaranteed. Pathogen reduction will most often require either long maturation times or a secondary composting or storage period outside of the toilet vault (WHO 2006).

For composting toilets in general, a strong commitment from the users or operators to maintain the system and a willingness to handle faecal compost is necessary. Most of the toilet systems are easy to use and maintain, so composting toilets can be applied in most parts of the world as owner-built or low-cost solutions as well as manufactured and high-tech products.

Composting toilets are a listed technology in the 2006 World Health Organisation Guidelines for the Safe Use of Excreta and Greywater (WHO, 2006) and are recognised by the Joint Monitoring Programme of the Millennium Development Goals as one of five possible systems of improved sanitation (UNICEF/WHO, 2008). These are: flush or pour-flush toilet, latrine connected to a piped sewer system, septic tank or pit latrine, ventilated improved pit (VIP) latrines, pit latrines with slabs, composting toilets.

1.2 Functional principles

1.2.1 Process

A composting (or biological) toilet system receives and processes excrement and toilet paper in a specially designed container or vault. Some composting toilets receive urine whilst others are specifically designed to receive only faeces, with urine being collected separately. Biodregadable household waste, including organic food waste, can also be added to the vault. The waste then undergoes a composting process there. Toilet systems that use heat for drying faecal matter in a vault rather than composting are called dehydration toilets (see gtz-Technical Review 02).

Composting degrades organic matter through thermophilic aerobic bacteria, fungi and actinomycetes. Under optimal conditions the bacteria produce temperatures within the composting heap in excess of 50℃ and thus can prov ide a fast and substantial pathogen reduction. To reach these temperatures the bacteria require a good aeration of the material, optimal moisture content and a specific carbon to nitrogen ratio (see Table 1). Human excreta and food waste alone do not provide these optimum conditions as both the water and nitrogen content are too high. A bulking agent is therefore added to lower the water content, improve aeration and increase the carbon content of the material.

The toilet itself consists of two basic elements: a place to sit or squat and a collecting or composting device. Additionally a ventilation system is favourable to ensure composting conditions and trap odour (see Figure 1). The conversion and removal frequency depends on the capacity of the container, the feeding rate and the composting conditions (mass reduction).

During the decomposition process, there is a considerable mass reduction through processes of evaporation, digestion and mineralisation (a reduction of up to 90% of the original volume) that allows a continuous storage of material in the vault. The final products are carbon dioxide, heat, water and compost. Composting is also a concentration process of salts and other nutrients, which must be considered when applying the final compost to the soil. Mixing with garden soil is recommended for plant compatibility and the nutritional requirements of the soil should be tested before first application.

Optimal conditions for thermophilic composting which will have the temperature to rise up to 50-70℃ include (note that optimal conditions are rarely achieved in composting toilets):

- Good aeration
- Moisture content 50-60%
- C/N ratio 30-35

1.2.2 Additives

As previously stated, human excreta and food waste do not provide optimum conditions for composting, as the water and nitrogen content is too high, particularly when urine is not separated. Additives or “bulking agents”, such as wood chips, bark chips, sawdust, ash and pieces of paper, are recommended to absorb moisture, to improve aeration by bulking up the pile and to balance the carbon demand by adding carbon-rich material. Bulking agents can also serve to cover the fresh faeces and thus lower the potential for fly contact and breeding, reducing the risk of disease transmission. If they are not added the material in the vault may compact to form impermeable layers, leading to wet and anaerobic conditions within the mass.

Some bulking agents can have an additional effect on odour (e.g. tannin in bark chips) as they bind the substances that cause bad smells. Lime and algae flower are essential additives to raise the pH when it is lower than 6.5, as many of the composting organisms can not survive in acid conditions.

Bulking agents must be added regulalrly to all composting toilets. Preferably a small amount is added after every use or at least once a day, depending on the degree of use, to cover the faeces and absorb the moisture to prevent bad smells.

1.2.3 Ventilation

The toilet vault is normally vented to improve aeration and the evaporation of excess moisture in the composting heap and to provide odour control through negative pressure. Ideally there should be an electric fan with speed control installed, to balance comfort (if air flow is too strong) with odour control (if airflow is too low) and to ensure that cooling and drying of the compost mass is avoided. Instead of an electrical fan, wind-driven fans, pipe insulation and passive solar heated outside surfaces may improve ventilation, but are less controllable. It should be noted that fly screens must be installed over vent pipes.

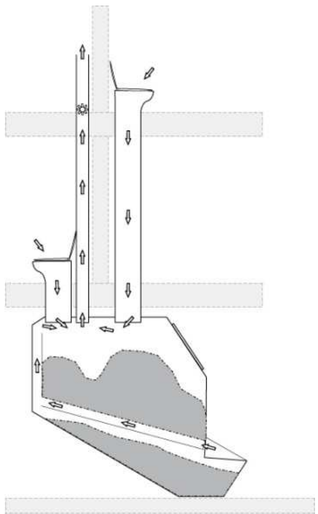


Figure 1. Cross section of a single-vault composting toilet, showing the ventilation system (source: Berger and Lorenz-Ladener, 2008).

1.2.4 Hygiene

Toilet compost is generally hygienically safe, if thermophilic composting occurs at temperatures of 55℃ for two w eeks or at 60℃ for one week. For safety however the Wor ld Health Organisation recommends a composting at 55℃ – 60℃ for one month with a further 2 – 4 months of f urther maturation in order to ensure a satisfactory pathogen reduction. However due to the relative complexity of ensuring optimal composting conditions in the vault these temperatures are rarely achieved in most composting toilet. Considerable pathogen reduction can be achieved in a composting toilet, but complete pathogen destruction usually can not be guaranteed.

This can however be achieved by a secondary co-composting with organic solid waste outside of the toilet vault with a periodic turning of the compost heap (1 - 2 times for one year in northern climates). Other treatment methods include long term storage, high pH, exposure to UV light, microbiological antagonists, and toxicological effects of metabolites.

Hygienic measures for handling the compost must be applied by all those exposed to it.

Faeces compost that is not exposed to high temperatures or otherwise hygienised should only be applied to ornamental plants, fruit-growing bushes and trees, not to food crops such as leafy vegetables and root plants. These plants should not be easily accessible to either animals or people to minimise the drgee of exposure.

Systems that collect urine in the vault produce a larger volume of leachate that needs to be carefully managed to avoid spreading pathogens. The handling, discharge and treatment of excess leachate must be considered in the planning phase of a composting toilet. For the treatment of urine from urine diverting toilets see GTZ (2009).

1.3 Available technologies

Available composting toilet systems can be classified as follows:

1.3.1 Toilet and storage facility in one unit or separated

Small compact designed units are equipped with a toilet seat and a mobile bucket or bin for intermediate storage on-site. Using a small storage space, the toilet can be installed at ground level, but the collected material must be transported to an external site for subsequent co-composting or any other treatment (digestion, fermentation etc.). The storage containers need to be emptied more often when compared to larger units with separate storage and treatment space in a basement. Transport and handling in small units may be made easier, if exchangeable buckets or bins are used.

Table 1. Suggested alternative recommendations for primary treatment of dry faeces before use at household level. No addition of new material (Source: WHO (2006).

Treatment	Criteria	Comment
Storage (only treatment) at ambient temperature 2-20℃	1,5-2 years	Will eliminate most bacterial pathogens, substantially reduce viruses, protozoa and parasites, some soil-b ova may persist
Storage and alkaline treatment	pH >9 during > 6 months	Temperature <35°, moisture content >25° or lower pH will prolong the time for absolute elimination

Larger composting toilet systems are mostly applied for year-round use in private houses or public toilet facilities. The toilet and the composting container are separated (e.g. the toilet is located at the ground floor and connected to a container in the basement of the building by a vertical tube). The material is stored directly for internal co-composting on-site in the same unit.

1.3.2 Single-vault or multiple-vault toilets

To provide the best conditions for self-heating of the heap and biological diversity, the storage volume of a vault should ideally not be less than 1 m³. Single-vault composting through continuous processing is feasible, if there is a separation between fresh and mature solid material. However, fresh liquids may contaminate the finished compost and compost from single-vault systems should undergo a second composting before application.

Multiple-vault composting by discontinuous (batch) processing avoids contamination, if the vault in use is strictly separated from the one not in use. The storage volume is generally smaller (for example 4 x 250 l) than in single-vault systems in order to save space, so self-heating and biological diversity may be limited. If the storage units are too small, maintenance and process control may be difficult. Double-vault systems are a good compromise, to achieve sufficient storage volume in both chambers as well as to minimise cross-contamination between the fresh vault and the maturing vault.

1.3.3 Urine diversion or mixed

The toilet bowl can be designed either with or without urine diversion facilities.

The moisture content of faeces when urine is kept out of the chamber is about 65-80%, which is sufficient for good processing with the addition of toilet paper and bulking agents. However, the compost may need to be watered, if moisture content falls below 40%.

When urine is diverted away from the vault, leachate production is reduced as are the efforts needed to balance the nutrient load with additives. It is particularly recommended for areas where treated urine is in demand as a fertiliser and it can be collected and applied at lower costs.

In most composting toilets without urine diversion, liquids will accumulate at the bottom of the vault which which must be drained off. The higher moisture and nitrogen content which resulting from the urine needs to be balanced by adding bulking material for optimum composting conditions. To avoid anaerobic conditions in the compost, designs usually ensure a drainage layer, a sieve-tray or a slope, so surplus liquids can be drained, stored and removed to a storage tank for further treatment.

Some designs evaporate leachate by electrical or solar heated devices (requiring an energy source and resulting in a loss of nutrients). Another possibility is to treat it in evapotranspiration beds. It can be reused as a liquid fertiliser for non-food plants, as concentrations of nutrients and organic carbon are high. Leachate should be handled with care, as it may contain pathogens and its handling, treatment and management must be considered thoroughly in the planning stage. If diluted with water (1:10) and protection measures such as subsurface application are in place, it can be applied to non-food plants.

1.4 Costs

1.4.1 Owner-built or commercially manufactured

There are many designs and models offered by manufacturers and dealers in many countries with a large range of prices, depending on complexity of the design, the numbert of units needed, transport costs, production and economic conditions. Functioning composting toilets can also be owner-built, if they are technical well constructed and assure the operational basics. Construction costs are mostly lower than manufactured toilet systems, particularly if local material is used and labour costs are low. Owner-built toilet systems provide options for low income areas and where official approvals are not required.

1.4.2 Low-tech or high-tech systems

Low-tech composting systems are basically storage facilities, in which excreta are collected and allowed to decompose at ambient temperatures. They may require more maintenance than semi-automatic systems and a greater degree of user involvement in the process but generally are much less expensive. High-tech units are usually more compact, if they are equipped with automatic mixers and thermostatically controlled heaters. They require less user intervention, if the technical equipment works reliably. However in case of breakdowns, special spare parts and servicing may be required. High-tech composting toilet systems are best installed, if space is expensive or limited and technical support is easily available.

1.4.3 Benefits

Benefits may arise from the final composted product and urine or leachate application to improve soil conditions and fertilisation. Operating costs (e.g. power supply, service, lifetime of the system) have to be balanced.

1.5 Applicability

Composting toilet systems can be constructed simply and relatively low-tech, or mechanised at an advanced technical level. Dry sanitation is particularly suited to arid regions and regions with no piped water or sewers. The equipment and operation of composting toilet systems can suit the technical conditions and cultural needs of both industrialised and developing countries. In some projects composting toilets have been successfully implemented in houses with up to four floors. In term of operation and maintenance, composting toilets are most suitable, if users are committed to operate the system carefully and to accept responsibility for its operation.

When compared to dehydration toilets, composting toilets require greater management efforts. The higher moisture content required for optimal composting conditions (around 50% compared to less than 25% in a dehydration toilet), means composting toilets need more care and intervention to function correctly (e.g. adding bulking materials to increase the carbon content and to absorb surplus moisture). Dehydration toilets tend to be more common in hot developing countries, as they require less investment and maintenance however the nutrients in compost are more easily available to plants than the product coming from a dehydration toilet.

Compared to VIP / pit latrines, composting toilets can be built as a permanent structure above ground and even integrated into the home. There is no need to dig a deep pit or to regularly replace the facility when pits are full, as the final product can be removed, handled and transported relatively easily when compared to faecal sludge.

Compared to water-flushed sanitation systems, composting toilets are usually less expensive than conventional septic systems or sewer systems, if costs for sewerage and wastewater treatment are considered. They will reduce household total water consumption by at least 25%.

2 General recommendations for operation

The main purpose of long-term and successful operation of composting toilets should be to provide safe and acceptable sanitation facilities for users, to establish an attractive environment and to gain safe end-products for reuse. Operation of composting toilets for private or public use therefore means proper cleaning, regular maintenance of the facilities and the process as well as safe treatment, handling and application of faecal compost, leachate and urine.

2.1 Cleaning

- To clean the toilet bowl, use a spray bottle with vinegar or citric acid, diluted by water. Both are biological disinfactants and avoid blocking of urine pipes, if urine is diverted. After spraying, faecal residues inside the bowl can be easily removed by hand, using toilet paper and dropping it into the compost bin.
- If necessary (for example in public toilets), use chemical disinfectants only for surfaces that are touched by hands (toilet seat, door handle, lock and tap).
- If the toilet facility is continuously left dirty by users, find out the reason and improve the conditions (e.g. sufficient ilumination or further information about proper use).
- Ensure that tissue paper or water for anal cleaning is available as well as water, soap and clean towels for hand cleaning.

2.2 Maintenance

- Check proper operation of the facility in accordance to the operation manual of the manufacturer or constructor.
- If there are problems (e.g. smell, flies, blockage of fluid), check the trouble-shooting list of the manufacturer or constructor and call him for advice.
- Add structural material (e.g. wood chips, straw clippings, dry leaves), if the material becomes too compact and humid. Aerate the material by turning with a tool e.g. pitchfork.
- Add water to the compost, if the material dehydrates (e.g. by heat or urine separation).
- Check air inlet and outlet for safe function of the ventilation, if smell should arise.
- Empty the storage or composting bin, when necessary, to avoid overload.

2.3 Composting and post-composting

1. Composting process always should be supplied by a mixture of various materials, like biodegradable garden or kitchen waste, grass or wood clippings, depending from availibility.

2. If pathogens must be completey destroyed, build up a compost heap of at least one cbm and cover it against rain, heat loss and dehydration to improve self-heating of the material.

3. Ensure that necessary composting conditions are achieved (moisture content, oxygiene supply, C/N ratio, pH, biological activity) and check temperature.

4. After two weeks of heat development (> 55°C) tur n the heap for another self-heating process.

5. Leave the compost for cooling down, so it can be applied to plants.

6. Use this method as a post-composting measure for material out of bucket and dehydration toilets as well as for compost from vault systems.

7. Other methods like vermi-composting or long-term decomposition are practical, when high temperatures during a certain period cannot be achieved and the compost is used for ornamental plants or non-leafy food crops.

Figure 2. Brick chamber for faeces composting equipped with vent pipes on the back side and sheltered (photo: W. Berger, 2009 at German Research project at Valley View University, Ghana)

2.4 Application and reuse of compost

- Check nutrient supply of the soil before being fertilised with compost (e.g. every ten years), to find out, if the soil is not oversupplied and to protect ground water.
- Compost as a fertiliser should be applied to plants during periods, when plants are able to adapt nutrients (e.g. during spring and autumn in European climates).
- Compost should be mixed with garden soil or sand to avoid overfertilisation, before being applied to the plants.
- Do not dig compost under the soil surface, but mix it a bit with the covering soil.

Figure 3. Applying faeces compost to the garden soil by mixing with a fork (source : Berger and Lorenz-Ladener, 2008).

2.5 Hygienic precautions and directives

During cleaning, maintenance and handling faeces compost, leachate and urine, it is recommended to use one-way rubber gloves and to wash hands afterwards. Only mature compost that looks and smells like rich garden soil or leaf humus should be harvested and post-composted before reuse. Fresh material similar to the original waste material must remain in the vault for further composting.

Figure 4. Mature compost from a single-vault composting toilet ready for soil improvement (source : Berger and Lorenz-Ladener, 2008).

3 Single-vault composting toilets

Single-vault composting toilet systems process faeces, urine (if not diverted) and organic household waste, together with bulking material. The basic process of the system is the decomposition of excreta inside one large container or vault.

3.1 Functional principles

The composting vault functions as a continuous reactor, with excreta being added to the top, and the end product (compost) being removed periodically from the bottom. Generally, the chamber is located beneath the toilet seat below the floor level. The large, mostly sloped-floor chamber allows long-term retention and facilitates aeration.

Excess liquids flow down to a separate liquid storage chamber. Humidity is needed to maintain optimal composting conditions. With time, natural biological decomposition converts human waste into a small amount of stabilised soil-like material. Retention time is at least 2 years before the final compost (about 40 l per person per year on a household level) can be removed. Non-stabilised material follows by gravity or manually, using tools for further treatment inside the container.

An extremely simple, low cost version of the single vault composting toilet, the Arborloo, has been developed for use in the rural African context. The Arborloo dispenses with the need to remove the compost and instead uses a shallow pit with a depth of up to 1,5 m to collect and compost faeces, soil, wood ash and dry leaves. When the pit is almost full the contents are covered with a thck layer of soil a young fruit tree can eventually be planted in the pit. Another shallow pit is then dug and the toilet superstructure is then move

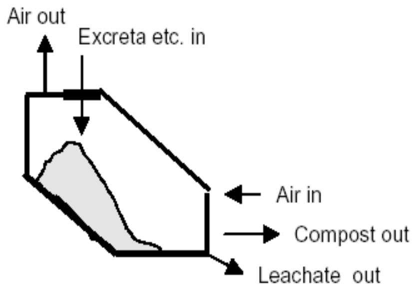


Figure 5. Flow chart of continuous composting toilet (source: Davison and Schwizer 2001) .

3.2 Operation and maintenance

Before starting operation, a layer of absorbing material (e.g. a mixture of biological active soil or compost and wood chips) should be filled into the compost container to provide a drainage base as well as a biological starter bed. On top of this layer, a cover of carbon-rich additives such as sawdust, wood chips or straw clippings, dried leaves or rice hulls is placed and moistened.

To ensure functioning of the composting process, regular mechanical movement of the mass using an aeration stick or a pitchfork may be needed. If conditions support earthworms or other digging soil fauna, these may assume the rolle of shifting the mass with time. Once the capacity of the vault has been reached, the compost at the bottom of the container must be continuously removed, at least once a year, enuring enough space for ongoing decompostion.

Empyting of the single vault toilet is less frequently needed than for multiple-vault systems. However, the weight of the larger mass can cause compaction, which requires increased maintenance to ensure good aeration. Regular maintenance is therefore very important to guarantee good system performance.

3.3 Extent of application

Single-vault composting toilets are the oldest and most common composting toilet models in many places worldwide. Typical applications of single-vault systems in industrialised countries include locations where there is no connection to a central sewer, such as in mountain huts, nature reserves or remote settlements. Single-vault composting toilets are also installed in many ecological settlements near urban surroundings.

Owner-built models, similar to the Clivus Multrum model, are very common in developing countries with warm climates, and the simple Arborloo is also gaining in popularity particularly in rural Africa. Urine diversion is generally recommended to minimise production of leachate and to prevent anaerobic conditions caused by high water content.

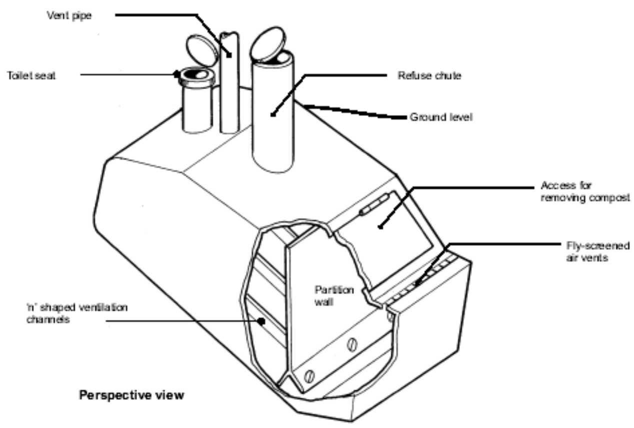


Figure 6. View of a single-vault composting toilet (source: Reed and Shaw, 1999).

3.4 Hygiene

In a single vault composter there is a risk that mature, sanitised material is mixed with fresh material, and thus recontaminated with pathogen organisms. Correct system design and careful maintenance is crucial to reduce that risk. If this cannot be guaranteed then a mulstiple vault system should be considered.

For the Arborloo, there is generally a low risk of exposure to either the compost or fresh faeces as these are covered and not removed from the shallow pit.

3.5 Cost data

The prices for manufactured systems range from EUR 2,000 for a model used only seasonally to up to more than EUR 8,000 for public use. Production conditions, environmental impact, life span durability and transport expenses should be regarded when comparing prices of the different models.

The Arborloo can be an extremely low cost model (costs to be obtained).

3.6 Good practice examples

In Hamburg, Germany, 36 composting toilets have been installed within the eco-settlement Allermöhe[1].

Figure 7. Left : Dry toilet with removable insert and sealed toilet seat. Right : Insulated single-vault composting container with upper lid for maintenance and lower lid for discharge and working platform (both Hamburg-Allermöhe, Germany, source: Berger and Lorenz-Ladener, 2008).

Figure 8. Owner-built toilet seat with storage for wood chips to cover the pile on a daily basis (Puerto Morelos, Mexico) (source: The ReSource Institute, see below).

Figure 9. Owner-built single-vault composting toilet with built-in toilet connection and outside access for maintenance and discharge (Puerto Morelos, Mexico) (source: The ReSource Institute, see below).

An owner-built Clivus Multrum-style model is organised by The Resource Institute in Puerto Morelos community, Mexico. This project is called Nahi Xix. For more information see: http://www.riles.org/projmex.htm

[1] See: http://www.susana.org/lang-en/case-studies/region/europe

4 Multiple-vault composting toilets

Multiple-vault composting toilets consist of two or more watertight, interchangeable chambers to collect excreta.

4.1 Functional principles

In multiple vault systems a vault is filled and left to mature whilst another vault is in use. Urine can be diverted from the vault if required. Generally these toilets are not used to compost organic household waste due to their limited volume. One example arrangement for a multiple-vault toilet consists of an underfloor processing vault with a cylindrical outer housing in which a slightly smaller inner tank is able to rotate. The inner tank is divided into four chambers (six on some models). The one in use is positioned directly below the down pipe from the toilet. When one vault is filled, the inner tank is rotated, positioning the next vault below the toilet. In this way each vault is filled in sequence.

On complete filling of all vaults, the material in the first vault is removed and emptied through an access door. Multiple-vault systems can allow the connection of two toilets, if they have at least four vaults – thus resulting in two double vault toilets. However if one of the two chambers in use is full both must be removed or moved on to start filling the empty vaults.

Double-vault toilets function similarly: There are two vaults with one being used first. When this vault is filled it is closed for further decomposition and the second vault is brought into use. When the second vault fills, the contents must be removed from the first vault, so the vault can be used again. Careful dimensioning is therefore needed to ensure that a sufficient time elapses before one vault fills and the other must be emptied to allow a sufficient maturation period. A secondary co-composting to ensure hygienisation may be necessary.

In double vault systems the toilet may be movable being placed above the vault in use, whilst the opening to the other vault remains closed. Once the first vault fills it is closed and the toilet seat moved to the second vault. Alternatively, the vaults themselves may be moveable under a fixed toilet (see also exchangeable bin-system).

In toilets where urine is not diverted, liquid can drain into a collecting tank by means of a sieve bottom or a slope. If not treated and used as a fertiliser, the leachate should be discharged into an evapotranspiration bed or a wastewater treatment process. The covering lids of the vaults may face the sun for additonal heating. This increases evaporation of leachate as well as the temperature of the composting process.

A low-cost double vault composting toilet, the Fossa Alterna, has been developed for rural Africa, which functions in exactly the same manner as more expensive systems, only that the composting vaults are shallow pits and the toilet superstructure is moved back and forth between the pits as they areused in alternation.

4.2 Operation and maintenance

Small multiple-vault toilet facilities require careful monitoring of the level within the vault in use and the emptying frequency is generally higher than in single-vault systems. Maintenance, such as mixing and raking of the material, is rarely required, as problems with compaction and anaerobic conditions are reduced through the smaller volume. Emptying of the chambers may be more comfortable and acceptable to users or operators than in single-vault systems, as the material is completely separated from fresh faeces. However, by dividing the whole composting mass into several smaller parts, the decomposition process may be less complete than in single vault-systems.

4.3 Extent of application

Larger multiple-vault systems are often constructed as outhouses separated from homes. Smaller systems can easily be integrated in homes, if proper ventilation is guaranteed.

4.4 Hygiene

The multiple-vault system avoids contamination of mature compost with fresh faeces and therefore reduces significantly bacterial exposure into the environment, compared to a single-vault system. Nevertheless, the final material should be post-composted before use as a fertiliser in garden or agricultural areas.

The World Health Organisation recommends the use of multiple vault toilets over single vault toilets due to the increased protection from exposure to fresh excreta that they offer.

4.5 Cost data

Manufactured multiple-vault toilet systems are available in different units of varying capacity at prices between EUR 2,000 and 3,000 (Hyttetorget, Norway). Prefabricated double-vault toilet substructures made of fibreglass can be offered between EUR 800 and 900 (Sirdo Seco, Mexico).

Running costs for multiple-vault systems are usually higher than for single-vault systems, due in part to the increased effort in managing the process. The benefit obtained from the product may be similar to other types of composting toilets. The double-vault system can be self-constructed by using cement blocks and coated inside and on the exterior for sealing, if groundwater intrusion could be a problem. Vault size typically is about 1.2 m by 1.2 m by 1.2 m for a total of 1.8 m^3 each.

Still need Fossa Alterna costs

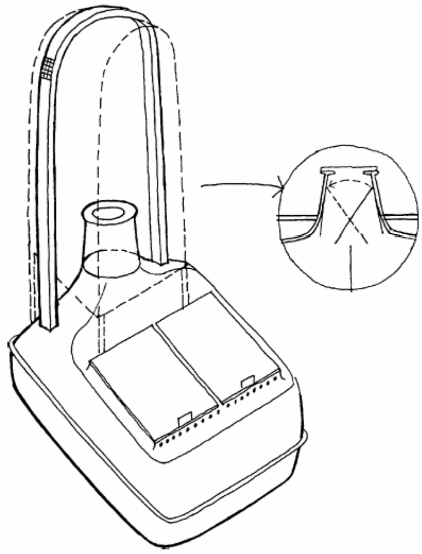


Figure 10. Sirdo Seco doube-vault toilet in Mexico (source: Winblad and Simpson-Hebert (2004).

4.6 Good practice examples

The Sirdo Seco toilet system is divided into two vaults inside a composting container, equipped with a sliding baffle between the toilet chute and the dividing wall of the two vaults. When one vault is filled, the baffle is switched by a handle, causing the excreta to slide into the other vault. Each vault has a volume of 1.2 cbm. If 6-8 people use it regularly, it needs to be emptied once a year at most. A ventilation pipe from the container to the roof top removes odours and has a screen on top to prevent flies entering the system. Both vaults are covered with lids made from black painted aluminium sheet, to increase evaporation by heating faecal matter. The Sirdo Seco has been used in Mexico for over 20 years. One particular advantage is its low weight construction, when empty. In case people living in squatter settlements are evicted at short notice, they may empty the toilet and take it with them.

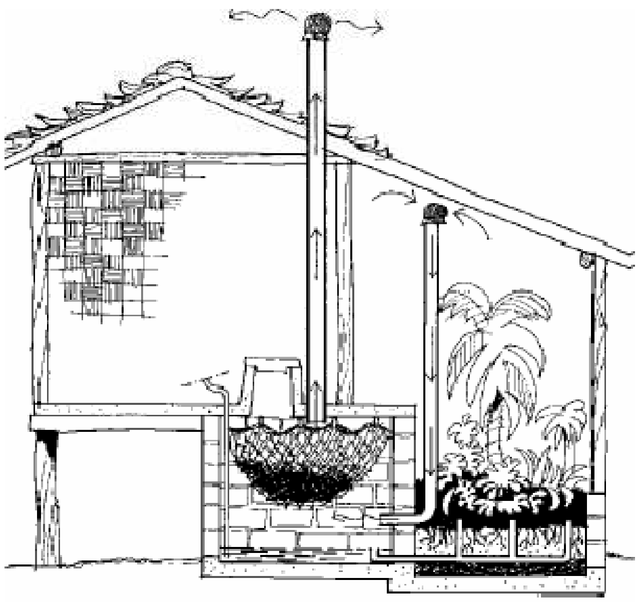


Figure 11. Cross section of the CCD composting toilet with attached greenhouse and evapo-transpiration bed (source: Winblad and Simpson-Hebert (2004).

The Pacific Island CCD toilet is being applied in the south pacific islands and consists of two watertight chambers built above the ground. Excreta falls on a mat woven from coconut palm fronds resting on top of a nylon fishing net that is suspended inside the composting vault to separate solid from liquid excreta. This false floor allows air to penetrate the compost pile from all sides. A large diameter vent pipe draws air from an intake opening located below the net along the rear wall of the vault. This airflow also helps to evaporate the liquids that accumulate on the floor of the digestion vault.

Evaporation is further enhanced by wicks made from strips of polyester or rayon fibre (from old clothing), which are hung from the net to draw up the liquid from below, increasing the surface area exposed to the air stream. Another solution is to drain the liquid to an evapotranspiration bed. Experiences with CCD toilets on the island of Pohnpei, Federated States of Micronesia, have shown that it takes a family of up to 10 people over a year to fill one composting vault. The solids in the vault have undergone biodegradation and all excess liquids had been evaporated.

5 Mobile bucket or bin toilets followed by composting of the excreta

Movable bucket or bin toilets are not composting toilets they are containers for excreta collection. They can function either as alternating removable buckets or as powered roll-away containers with quick-disconnect couplings for toilet, exhaust and leachate drain connection. Some systems use commercially available roll-away "wheelie" bins, some use any kind and size of buckets, equipped with a lid and a handle to carry by hand. Composting does not occur within the receiving container.

For the bucket or bin toilet to become part of a composting system, the relatively fresh excreta must be removed regularly for composting on a compost heap or in a compost bin.

5.1 Functional principles

One container (bin or bucket) is placed under the toilet seat or toilet chute and is replaced when full. The content in the first bin is further stored for treatment preferably on-site (for example in a compost pile, composting container, or by fermentation) or off-site (in a composting or biogas plant).

Some systems use urine diversion, others collect both urine and faeces in bins that usually need absorbing additives and have a drainage system for leachate. Other systems that can also be classified as movable bin systems, are compact dry toilets that collect faeces and sometimes also urine in small receptacles integrated in the toilet unit. Receptacles may be simple plastic or biodegradable bags too.

To prevent odour and improve evaporation, most of the toilet models are equipped with a ventilation system, either operated by natural negative pressure or by electrical power.

Figure 12. Urine diverting dry toilet with bucket underfloor (Wostman Ecology AB, Sweden)- still to come

5.2 Operation and maintenance

The collection bins and buckets need to be regularly emptied and replaced. To avoid having to clean containers after emptying, biodegradable bags usedas a liner are comfortable and hygienic. They last several weeks for collecting faeces, if urine is diverted. Treatment is most often carried out in a compost heap or bin on site. Several advanced composters, handling options, turning tools and measuring instruments are offered by specialised suppliers.

Urine or leachate needs to be handled, stored and treated for reuse. Urine is usually easier to handle than leachate, as faecal contamination is reduced.

5.3 Extent of application

Toilets with movable buckets and a small capacity are available for non-permanent use such as holiday homes and allotments. Due to their small size, they are self-contained and do not require the larger vault associated with single or even multiplevault systems, but the emptying frequency is much higherand there is a need for on-site or near to site composting facilities. This may hinder acceptance, if user frequency is high and users are responsible by themselves for emptying the collection bin and subsequent composting.

Figure 13. Movable bucket toilet for the addition of sawdust or bark chips. Exchangeable buckets and biodegradable bags can be used (source : Berger Biotechnik, Germany)

The larger bin system is best suited to large-scale operations, where a pick-up service empties the bins and transports the contents to a central or semi-central treatment facility. Emptying and treatment of the excreta would no longer be part of the user's responsibility, unlike in some other composting toilets and a degree of comfort comparable with that of conventional flush toilets would be provided and may therefore be accepted easier. By treatment of the collected excreta in larger external units, the decomposition process can be controlled and better quality results of the final product maybe achieved.

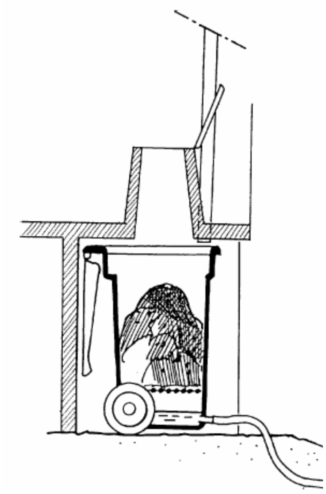


Figure 14. Schematic diagram of movable bin composting toilet (source: Winblad and Simpson-Hebert (2004).

5.4 Hygiene

Full collecting bins or buckets must be correctly closed with lids to avoid exposure and smell during transport or intermediate storage before treatment. Further adequate protection measures during handling of the contents should guarantee that health risks to users and service staff are minimised. Some of the smell can be absorbed by additives such as bark and wood chips and will be necessary when ventilation of the collecting container is not possible.

Composting and pathogen inactivation does not occur within the collecting containers, so a correct composting is an absolutely essential before it is used on plants. If the contents of the bins is collected and centrally treated in a composting plant, pathogen free compost can be achieved.

5.5 Cost data

The collection part of the system is easy to construct for owner-builders, since locally available or even second hand bins and buckets can be modified to be used as a collection container. Specifically manufactured bins with connections for ventilation and leachate drainage are more expensive but much cheaper than single or multi-vault composting toilets. Costs for manufactured bucket toilets range from EUR 50 - 250, for bin toilets with higher capacity from EUR 200 to 600. Cost savings may be obtained in larger schemes with a collection system and a central treatment plant.

The collecting container however is only one part of the complete composting toilet system and a composting facility with restricted access to minimise exposure will be required to ensure treatment. This will add some additional costs.

Benefits obtained from this system after treatment may prove to be relatively higher than for other compost toilet models due to the lower investments, if the extra efforts for operation and treatment are not counted. Central co-composting with domestic organic waste may be an economically reasonable solution in densely populated areas, if there is a local demand for compost.

Figure 15. Movable ventilated collecting bins with overflow for leachate discharge (source : PikkuVihreä, Finland)

5.6 Good practice examples

An example in Kiribati uses two 240 litre standard wheeled plastic refuse bins for collection. There is a false floor of mesh near the base of each bin, which allows liquid to drain to the base, equipped with an overflow-pipe to a sealed evapotranspiration bed. Air is drawn into the bin through a cut-out near the base and comes into contact with the bottom of the material through the mesh-floor. In addition, perforated ventilation pipes running vertically along the inside walls of the bin help to aerate the pile.

Figure 16. Part view of the multi-story houses in Dong Sheng, showing vent pipes on the roof from the ventilation system (photo : W. Berger, 2009).

Figure 17. Schematic diagram of movable bin composting toilet (source: Winblad and Simpson-Hebert (2004).

The Erdos Eco-Town project in Dong Sheng, Inner Mongolia, China, is the largest project worldwide with composting bin toilets. The project is supported by the Swedish government and covers more than 800 households in 4-storey buildings. The urine diverting dry toilets were specially designed for this project and are made of sanitary ware. Each toilet is equipped with a “flushing” device for sawdust and a turning bowl to prevent people seeing into the down pipe, which is connected to an individual collection bin in the basement of the buildings. Trained staff members are responsible for information, consulting, maintenance and collection of faeces and treatment in the local eco-station (composting of faeces, greywater treatment and solid waste sorting).

Although generally successful, long-term experiences in operation and maintenance have shown that improvements in planning, construction and realisation are necessary and investments for optimisation measures should be implemented from the start for pioneer projects. Because of the serious deficiencies causing immense efforts for retrofitting, the dry toilets will be substituted by low-flush toilets. In this way, the project offers a large area for lessons learnt.

Figure 18. Left : Ceramic urine diverting dry toilet equipped with turning bowl, automatic sawdust supplying device and trap for urine. Right : Downpipes coming from each floor leading into separate bins with housing (Erdos Eco-Town, Dong Sheng, China, photos: W. Berger, 2009)

For further information download the initial project description : http://www.ecosanres.org/pdf_files/ESR-factsheet-11.pdf

The Gebers collective housing project near Stockholm, Sweden, consists of apartment buildings for 80 inhabitants and it was a model for the Erdos project in China. There are dry toilets with urine diversion in each apartment. Urine is collected in a tank in the basement and is reused in agriculture after further external storage. Faeces fall straight down through pipes into individual ordinary 140 l dust bins in the basement. The bins are removed when full and transported to a nearby composting site.

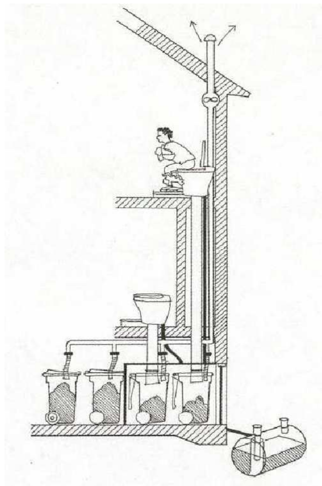


Figure 19. Sketch of the movable bin system at Gebers appartment block in Stockholm, Sweden (source: Winblad and Simpson-Hebert (2004).

For further information download the project data sheet: http://www.gtz.de/de/dokumente/en-ecosan-pds-008-sweden-gebers-2005.pdf.

6 Composting toilets with mechanical devices

Several manufacturers offer technically sophisticated designs, equipped with mechanical devices and electrical heaters, to speed up evaporation and degradation. The devices help to increase capacity or minimise space and to simplify maintenance.

6.1 Functional principles

The basic principle of most of these toilets is to mix faecal matter with sawdust or a similar organic material, by turning or stirring devices located inside the vault. Intermittent moving improves aeration, intensifies the contact with microorganisms in the matrix and thus increases the decomposition of the content. The mixing device can be mechanically driven and operated by hand or foot, (e.g after each use) or electrically driven and activated by pressing a button or automatically by sensors. Continuous ventilation is necessary to prevent odour and to ensure air exchange.

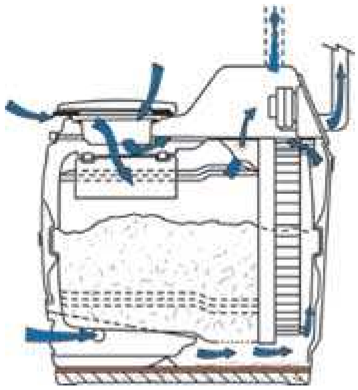


Figure 20. Cross section of turning drum facility with enforced ventilation (Source : Sun-Mar, USA)

Many systems can also handle urine, but more carbonic absorbing material and heating energy is needed tto manage the excess liquid, if it is not drained. Evaporation of liquids through heat may be preferable in climates with cold temperatures to avoid freezing. Urine diversion enables smaller systems to be built, if provision for urine collection and use or discharge is made. However, moisture content of the material must be observed either with or without urine diversion, to prevent sludge accumulation or crustification. Stirring devices are generally also advantageous for dehydration processes of faecal matter.

6.2 Operation and maintenance

Handling and maintenance requirements depend on whether batch or continuous systems are used.

In batch systems, composting bins are filled with sawdust or similar charge materials before use. During operation, no further additives are needed, but the condition of the mixture should be checked regularly to make sure that it does not dry up or gets too wet. After being filled up and a decomposition period of at least 6 months, the bin has to be emptied completely and a new load of charge material is put into the bin for starting another filling. Batch systems, each equipped with mechanical and electric devices, are mostly run on a large scale because technical expenses are high.

Continuous systems are filled with a layer of biodegradable charge material (e.g. sawdust) before first use. However, some additives need to be supplied regularly for proper operation. The system enables a regular extraction of small volumes of mature compost at frequent intervals (e.g. once a month), whilst fresh material remains in the treatment chamber for further processing. The final product of both systems should undergo a second composting before being applied to the soil for fertilisation.

6.3 Extent of application

System sizes vary from small individual models that can be installed for example in a private bathroom, to large models for public toilets or even for processing organic waste from industries. Power supply is needed in most systems for heating, mixing devices and a fan. Connections for ventilation and, if excess liquid is discharged or urine diversion is provided, a storage tank or a pipe connection for further treatment are required.

Figure 21. Cross section of a toilet facility with horizontal stirring unit (source : Seiwa Denko, Japan)

Large systems such as the larger versions of the Japanese BioLux are usually detached from the toilet and located beneath bathrooms or toilet cabins. A volume of 1 m³ of sawdust is required for 150 to 200 users per day. Systems that process urine together with faeces require much more energy for evaporation of excess liquid than the systems with urine diversion that use heating only for maintaining optimal temperature of the compostig process.

Small systems, as the Scandinavian Biolan Naturum or the Biolet, are designed for a small number of users. They are very compact and can be installed in bathrooms of individual houses or allotments for non-permanent operation. They use continuous processing and are available with mechanical or electrical mixing devices, both with or without heating systems. Urine is diverted and collected separately.

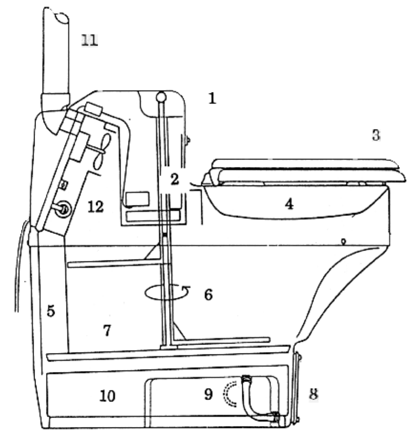


Figure 22: Cross section of a compact toilet with vertical stirring unit (source: Biolet USA/Switzerland)

Generally, application of prefabricated automatic or semi-automatic toilet systems is mostly limited to industrialised countries due to their relatively high prize and the difficulty to reproduce them easily on a local level.

6.4 Hygiene

Systems that are equipped with heating devices to evaporate urine and/or to maintain optimum conditions for composting and pathogen destruction may achieve pathogen-free material, if the process is controlled by thermostats to guarantee a constant temperature above 50 to 60℃. However, the final product may be too concentrated with salts and nutrients, so mixing with poor soil and post composting is recommended. Also systems without permanent operation conditions may require further treatment of the material for safe reuse.

6.5 Cost data

Composting toilets with mechanical devices mostly are more expensive than other types of manufactured composting toilets because of higher technical efforts. Systems that evaporate urine have high electricity consumption. Urine diversion allows avoiding this negative aspect. By the help of mixing devices, the requirement of manual maintenance is reduced, compared to other types of composting toilets.

Efforts for post-treatment or other safety measures before reuse of compost are lower than in many other types of composting toilets, as the hygienic quality may be generally better under stable conditions. The systems may optimise the composting process and minimise user involvement. As far as power supply is available, they can be used in situations, when other composting systems cannot be applied.

6.6 Good practice examples

Asahiyama Zoo, located in the northern part of Japan, attracts thousands of visitors every month. Since 1997, a total of 12 composting toilets (BioLux) have been installed. Almost all units treat both faeces and urine together and few treat only urine. Survey results showed that the system had gained great acceptability not just by the staff of the zoo, but especially by the users. In relation to this good result, the management is planning to use the system to treat animal wastes as well (Asahiyama Zoo, Kuranuma, Higashi Asahikawa-cho, Asahikawa City, Japan).

For further reading download : http://www.gtz.de/en/dokumente/en-ecosan-pds-030-automated-compost-toilet-asahiyama-zoo-2006.pdf

7 References

BERGER, W. and LORENZ-LADENER, C. Ed. (2008) Komposttoiletten – Sanitärtechnik ohne Wasser, Ökobuch-Verlag, Staufen, Germany. Table of contents: http://www2.gtz.de/Dokumente/oe44/ecosan/de-TOC-ONLY-kompost-toiletten-ohne-wasser-2008.pdf

DAVISON, L. and SCHWIZER, B. (2001) Waterless Composting Toilets, septic safe, Environment & Health Protection Guidelines: On-site Sewage Management for Single Households, Perth, Australia. Download: http://www.clearwater.asn.au/resources/523_1.322_TD_JW_DavisonCompostingtoilets.pdf

DEL PORTO, D. and STEINFELD, C. (2000) The Composting Toilet Book, CEPP, Concord, MA, USA.

ÉLAIN, C. (2005) Un petit coin pour soulager la planète, Èditions Goutte de Sable, Athée, France.

FRANKEN, M. (2007) Gestión de agues, Conceptos para el nuevo milenio, Plural editors, La Paz, Bolivia.

FUNAMIZU, N. (2006) Dry Toilet: An Important System for Controlling Micro-pollutants from Our Daily Life. Proceeding from the 2nd International Dry Toilet Conference, 16-19 August 2006 in Tampere, Finland.

GTZ (2009) Technology Review 1: Urine diversion - Overview of urine diversion components such as waterless urinals, urine diversion toilets, urine storage and reuse systems, http://www.gtz.de/en/themen/umwelt-infrastruktur/wasser/9397.htm

HARPER, P. and HALESTRAP, L. (1999) Lifting the Lid, An Ecological Approach to Toilet Systems, C.A.T Publications, Machynlleth, UK.

JENKINS, J. (1999) The Humanure Handbook, A Guide to Composting Human Manure. Jenkins Publishing, Grove City, PA, USA. Download: http://humanurehandbook.com/downloads/Humanure_Handbook_all.pdf

KUNST, S. et al. (2002): Sustainable Water and Soil Management. Springer Verlag, Berlin, Germany.

MORGAN, P. (2007) Toilets That Make Compost, Eco-SanRes, Stockholm Environment Institute, Stockholm, Sweden, http://www.ecosanres.org/pdf_files/ToiletsThatMakeCompost.pdf

PEASEY, A. (2000) Health Aspects of Dry Sanitation with Waste Reuse. Water and Environmental Health at London and Loughborough. Task No. 324. London, UK. Download: http://www.lboro.ac.uk/well/resources/well-studies/full-reports-pdf/task0324.pdf

REED, B. and SHAW, R. (1999) Using Human Waste. Water and Environmental Health at London and Loughborough, Technical Brief No. 63, London, UK. Download: http://www.lboro.ac.uk/well/resources/technical-briefs/63-using-human-waste.pdf

SCHÖNNING, C. and STENSTRÖM, T.A., (2004): Guidelines on the Safe Use of Urine and Faeces in Ecological Sanitation Systems, EcoSanRes Publications Series 2004-1, Stockholm Environment Institute SEI, Stockholm, Sweden.

VAN DER RYN, S. (1978) The Toilet Papers, Recycling Waste and Conserving Water, Ecological Design Press, Sausalito, California, USA.

WHO (2006) Guidelines for the safe use of excreta and Greywater, World Health Organisation, Geneva, Switzerland, http://www.who.int/water_sanitation_health/wastewater/gsuww/en/index.html

WINBLAD, U. und SIMPSON-HERBERT, M., Ed. (2004) Ecological Sanitation, Stockholm Environment Institute, Stockholm, Sweden, http://www.ecosanres.org/pdf_files/Ecological_Sanitation_2004.pdf

UNICEF and WHO (2008) Progress on drinking water and sanitation: special focus on sanitation, http://www.who.int/water_sanitation_health/monitoring/jmp2008/en/index.html

8 Appendix: Range of manufacturers and commercially available composting toilets

A list of suppliers of (engineered) composting toilets with costs is provided in a separate file (to keep the file size of this document down), see here:

http://www.gtz.de/en/themen/umwelt-infrastruktur/wasser/9397.htm