INTEGRE

Compost toilets

AND THE POTENTIAL FOR USE IN THE PACIFIC ISLANDS

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Use in the Pacific Islands

Dry Toilets, or Waterless Compost Toilets (WCT) can provide excellent toilet facilities where there is no piped municipal sewage system, or septic tanks are inappropriate or not feasible due to restricted water supplies. A WCT, generally referred to as a 'Compost Toilet', works on the principal that microbes can be used to break down the human excreta into a form that is safe and sanitary, but can also be used for plant fertilizer after some time, so providing an end use for the human waste. To ensure the microbes do their job effectively, the conditions in the toilet chamber, into which the human waste is deposited, must be such that the microbes will thrive.

For the compost microbes to survive and do their job well, they must have plenty of oxygen, to encourage an aerobic process to take place, some moisture - but not too wet - and sufficient time. The compost pile also needs the addition of a dry high carbon material - called a Bulking Agent - to ensure that the right amount of carbon is available to mix with the high nitrogen content of the human waste. This ensures that proper composting can take place.

Exemple de toilettes sèches en Angleterre

Sciure pour toilettes sèches, photo : DocteurCosmos

SANITATION

Pathogens - the potentially dangerous microbes that can cause intestinal diseases - are killed by both heat and oxygen, as their preferred environment is the human gut. Where temperatures significantly exceed the normal human temperature of 37°C, and oxygen is present, the pathogens will be killed. The composting process generates heat, so that the higher the ambient temperature of the environment, the hotter the pile can get. This fact means that compost toilets in temperate and tropical environments work very well; all pathogens - with the exception of roundworm eggs if present - will be killed in 60 days as long as the compost pile is working reasonably well. It is only in the cooler temperate climates, with longer, colder winters, that the compost process will be cold enough to be largely ineffective during winter[1]

[1] *In such cool places a compost toilet needs longer to break down the waste and kill pathogens.*

OPERATION AND MAINTENANCE

As with any toilet, the facility must be kept clean, and simple maintenance conducted. With compost toilets, the operation is as important as the initial design: the Bulking Agent must be always available in the toilet for immediate addition after each use; the right amount of Bulking Agent - often sawdust - must be added after each use (a handful or a cup full); the pedestal must have a close fitting lid and this must be kept closed when not in use; the chamber must be emptied to a schedule - depending on design. Where a urine catching system is used, this needs flushing with a little water regularly to avoid smells. A hand basin for washing hands - as in any toilet - is a very good addition, and can be fed from rain collected off the roof. The drain from the sink should either go into any urine catching containers, for use on plants, or into the urine pipework for flushing the pipe, with an outlet onto suitable plants next to the toilet.

Placing a Banana Circle, or a similar plant arrangement, next to the toilet to accept any drain water and leachate from the chambers is an excellent way to ensure that there are no unsanitary leakages from the toilet system.

This report has a User Guide to Operation and Maintenance at Appendix I.

DESIGN TYPES

There are several basic designs that can be followed for compost toilets, and all types will give good results if properly constructed and operated. Some types are easier for owner-builders, whilst others are mores suitable for commercial designs that are sold to fit inside houses. There are two main types: 'Batch Processing', being those that deal with compost in batches, filling a container and then allowing the compost pile to compost for some time without additional inputs; and 'Continuous Processing', where the compost is extracted from the bottom of the unit over time, whilst it is still in use. The second type is typically used for inside houses. This report, and associated construction and user guides, concentrates more on the batch processing types, as these are easily owner-built, require simple materials as might be found in remote rural and outer island locations, and being the simplest and cheapest, are the type most likely to be taken up by rural people in French Polynesia, the overall purpose of this report being to provide information to such an audience.

This report covers the main points of the different design types, with simple construction drawings provided at Appendix II. There is also an associated Construction Guide produced alongside this report that provides more specific details about how to build a double chamber batch type compost toilet. The double chamber type is the simplest and cheapest design; the Construction Guide seeks to convey the key design points, whilst allowing the individual builder the opportunity to customise the construction to the materials and techniques available in their place. As such, it is not overly prescriptive, nor provides a detailed material quantity survey.

REGULATIONS AND STANDARDS

In Australia and New Zealand, an official Standard[2] is in place to provide both companies who sell and install the toilets, and local governments who approve them, with the necessary information to ensure that the toilets are sanitary and fit for purpose. The Standard is voluntary at this time, as there is currently no legislation regarding compost toilets. However, if any legislation is passed in Australia or New Zealand in this regard, then the Standard would no doubt be referred to in Regulations and so become a legal requirement.

The use of compost toilets is widespread in rural Australia and New Zealand, and they have been found to be far more preferable than the simple 'long drop' approach which uses a deep hole, does not encourage composting of the waste, requires frequent relocation of the toilet building, and has the potential to pollute local waters where they are close to the surface. Compost toilets have become particularly popular in rural areas subject to drought as household water use is dramatically less when using a compost toilet.

[2] *AS/NZS 1546.2-2008*

USE OF COMPOST MATERIALS

The composted output of a compost toilet should look nothing like what went in. It should be like commercial potting mix sold to gardeners: dark, crumbly, a little bit moist but not in any way noticeably wet, and no smell (see figure 8 in Section 6.4 below). Compost can be dug out of the chamber with a shovel; there is no need to completely clean the chambers, in fact, leaving some compost behind helps to kick off the next round. Where wheelie bins are used as the containers, these can be simply tipped out. Best and safest results are obtained when the compost is left inside the chamber - for over 6 months and best one year - after inputs have ceased, and then the compost removed is placed into a shallow pit and covered with earth for another year or so before using on the garden.

PACIFIC ISLAND EXAMPLES

This report does contain some examples from the Pacific Islands, but feed back from actual users of previous projects to introduce compost toilets, in the Marshalls Islands and Tuvalu, has been difficult t obtain. The author has over 25 years direct experience of building and using compost toilets in New Zealand and elsewhere, and built one for use in Kiribati. The results and impressions gained are included in the report.

A significant problem in the Pacific Islands has been to find a free Bulking Agent to use with the toilets. Where no Bulking Agent is used, the toilet will not work well, will likely smell, and the compost process is disrupted. Sawdust is almost universally used in Australia and New Zealand, but is not widely available in the Pacific, particularly in outer island atolls, the place where the toilets have the most useful application due to water constraints and poor soils for gardens. Casuarina needles were successfully used in Kiribati; coconut husk fibre, pulled out so it is very loose, and even shredded, should work well. A readily available, woody, high carbon, material with a high surface area to volume ratio is the fundamentals requirement. Fine leaf litter from under bushes is very successfully used in New Zealand, and this can be easily scraped up off the ground, by hand, in the Pacific islands too; a bucket full will last several weeks normally, and it is free. Collection of the Bulking Agent becomes is just another household task to fulfil.

CONCLUSION

Compost toilets can address the serious problem of how to provide sanitary toilets for outer island and rural Pacific Islanders. The toilets will use very little water, can be as safe and sanitary as any other type of toilet, and can produce an output of compost that is a welcome addition to anywhere with poor soils. The cost is far cheaper than a septic tank system, with associated earthworks, water supply, flush toilet system and pipe work. Any toilet needs a building to enclose the pedestal, and so the cost of the building is something that any toilet design must address. Well constructed and operated, compost toilets will not pollute surrounding waters. Official design rules are available in the Standard to ensure that builders can produce well made toilets.

Compost toilets turn a significant problem into a useful resource. Why there are not more of them in the world is potentially a great mystery.

Contents

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Introduction to Dry Toilets

MODERN TOILETS ARE ALMOST ALWAYS WATER FLUSHING TOILETS, USING WATER TO WASH THE HUMAN WASTE INTO A PIPED SEWAGE SYSTEM OR A SEPTIC TANK.

These toilets require large water inputs, and significant infrastructure if they are to work correctly. Dry, or compost, toilets, are widely used in rural areas in Australia and New Zealand where water supply is restricted, and use of septic tanks might cause local pollution. The output from a Compost toilet is a valuable garden soil conditioner and resource. The key points of dry toilets are as follows:

- **Low water use:** they require no external water supply, except for washing of hands after use;
- **Cheaper to build than flushing toilets with septic tanks:** especially where septic tanks are expensive to properly construct with suitable drainage fields;
- **Operation is as important as design:** users must take clear, but simple steps to operate a dry toilet effectively, using addition of a high carbon 'Bulking Agent' such as sawdust;
- **Produce a valuable resource:** the compost produced is a high quality soil conditioner, prized by gardeners;
- **No external pollution:** where properly constructed, any excess liquid is drained off into an adjacent biological processing area provided by suitable plants;
- **Sanitary and safe to use:** follow the instructions concerning sufficient composting times and procedures and all pathogens will be killed.

This report will use the term 'compost toilet' in most references to dry, waterless toilets, in recognition of the fact that the composting process is an essential part of a sanitary, clean and safe dry toilet design.

A dry toilet, called a Waterless Compost Toilet (WCT) in the official standards nomenclature of Australia/ New Zealand, relies on an aerobic process containing sufficient oxygen, along with the addition of extra carbon, to ensure that a good composting process occurs. Any pathogens in the human waste manure are killed by both the heat generated by the natural composting process, and the oxygenation that occurs, as these pathogens normally thrive in the anaerobic (non-oxygen) environment of the human intestines. If the compost pile becomes too wet the process becomes anaerobic, reducing the composting process and taking longer to kill pathogens.

A GOOD COMPOSTING TOILET PROCESS REQUIRES:

- **Nitrogen and Carbon:** nitrogen-rich human manures, and added carbon-rich material, called a 'Bulking Agent' (often sawdust or a similar fine material) in the right proportion of around 1: 30 nitrogen to carbon;
- **Air:** for aerobic - oxygenated - decomposition, not too much, but enough to keep the decomposition process running nicely;
- **Moisture:** to activate and sustain the living breakdown processes;
- **Microbial life:** primarily bacteria, which actually do much of the breakdown work.

This report is largely concerned with the potential to use dry, composting toilets in rural areas in the tropical and sub-tropical Pacific Islands, using readily available materials and a minimum of imported requirements. The recommended design for a demonstration compost toilet is that of the double chamber type, which is simple to build and operate, and allows sufficient composting time to kill all pathogens[3] prior to removal of the compost from the chambers, so minimising potential exposure to unsanitary pathogens.

[3] *With the possible exception of roundworm eggs which, if present may take two years to die*

2

Operating Principal of Compost Toilets

COMPOST TOILETS OPERATE USING THE PRINCIPAL OF COMPOSTING, WHICH IS, IN SIMPLE TERMS, THE BREAKDOWN OF ORGANIC MATERIALS THROUGH NATURAL PROCESSING BY MICRO-ORGANISMS. A SUCCESSFUL COMPOST TOILET DESIGN WILL ENCOURAGE THIS PROCESS TO WORK MUCH BETTER THAN IF THE HUMAN WASTE MANURE IS SIMPLY LEFT ALONE IN A PIT OR BURIED.

2.1 THE COMPOSTING PROCESS

Composting is a natural recycling process where manures and vegetative matter are converted into the soil matter of humus, containing nutrients that are then suitable for uptake by plants as their food. It uses animal and plant 'wastes' (manures and decaying plant matter) and converts them back into nutrient resources for plants, so that the waste is recycled into the local ecosystem; thus there is no waste as such. Composting is a natural process that closes the loop of food to wastes and back to food again. The term 'Composting' refers to techniques to accelerate and improve the natural degradation process.

When composting is used in a dry toilet, those natural processes are being managed in a way that allows a rapid breakdown of the waste, and then reuse of the available nutrients, through an aerobic (oxygen rich) conversion of 'wastes' into a rich soil matter that is both beneficial to any soil and plants to which it is added, and harmless to people.
Compost is something that most gardeners and farmers actively make to feed their plants. There are many different ways of making compost and managing the composting process. It can be done slowly over time, with a gradual conversion and feeding of the soil, such as vegetative mulches on gardens or crop land. It can also be done more quickly, over a few weeks and with the right amounts of air and water. With the right mix of manures and vegetation, heat-generating microbes become active, and sufficient temperatures can be achieved to destroy plant seeds and kill pathogenic microbes. This destruction of pathogenic microbes through heat generated by the compost process is the key factor that makes a Compost toilet a good option for sanitation in areas without a good water supply or sewage treatment system.

Good composting requires:

- **Organic Matter** – Nitrogen rich 'Green' material, such as fresh grass and manures; and Carbon rich 'Brown' material, such as leaves, straw and small woody debris;
- **Air** – for Aerobic decomposition, by the right microbes, to a readily available nutrient form;
- **Water** – Just enough for the moisture to activate and sustain the living breakdown processes;
- **Life** – microbial life, including bacteria, fungi, insects and worms that inhabit living soil, and that breakdown the waste materials into garden-ready compost.

In a fast composting process where heat is generated, such as often used by gardeners, the 'green' and 'brown' materials are mixed to give an appropriate Carbon to Nitrogen ratio, of around 30:1. The materials are laid in thin layers to allow easy access to both materials for the microbial life. The layers are well watered to be damp - but not wet - and are kept sufficient bulky to allow effective air circulation through the pile. The compost heap may be turned over frequently, depending on climatic conditions and temperatures, to reactivate a hot breakdown.

A good mix of carbon and nitrogen will break down over time, when moist and well aerated, as cold composting. There is less loss of nutrients with cold composting, but well aerated conditions over a long period of time are required to ensure the die-off of any pathogenic microbes, which survive in anaerobic (oxygen lacking) environments.

Pathogenic microbes die in oxygen rich environments and can be killed by heat.

There are, thus, two ways in which composting eliminates pathogens:

- **Air** – aeration supports aerobic breakdown microbes which displace anaerobic microbes.
- **Heat** – hot breakdown (by thermophilic microbes) rapidly kills pathogenic microbes.

Compost toilets work better in hot countries than in cold, as the composting process heats up quicker because the ambient temperature is higher, so killing pathogenic microbes quicker. Only roundworm eggs, if present, might last more than 60 days or so in a tropical compost toilet.

3

The Basic Design of Waterless Compost Toilets

COMPOST TOILETS CONTAIN HUMAN MANURES (FAECES AND URINE) IN A CHAMBER OR BIN WHERE COMPOSTING PROCESSES CAN TAKE PLACE.

There are many different types of containers and methods used, with some units having mechanical turning or rotating drums, with dedicated heating elements and forced ventilation also used to reduce moisture content. Compost toilets are commercially available as complete systems to install in existing buildings, or home built.

In all cases, the human excrement is retained in a container where there is sufficient air circulation for aerobic composting to take place (that is, lots of oxygen present). Generally the container is large enough to store the excrement for a long enough period to allow composting to a material that looks like gardener's potting mix. Some systems use special compost worms, called a vermi-composting process.

Examples of some common Compost toilet systems are outlined in Section 5 below, with descriptions of their construction and use. Apart from the construction and design of a particular compost toilet, the most important thing about the composting of human manures is the toilet operation, and the handling and reapplying of the compost material. Guideline notes for systems that are being consented under municipal regulations should cover operational details and the manner in which the compost material is reused[4]. Appendix I provides a set of guidelines for toilet operation as part of a User Guide.

All compost toilets require the addition of a 'Bulking Agent' which is high in carbon and surface area; sawdust or wood-shavings are often used. The Bulking Agent is required to lift the ratio of carbon to nitrogen needed for good composting to take place. A single handful added to a deposit is usually enough: often, too much bulking agent is used in an attempt to cover the human waste from sight, but this can mean too much carbon is added. The best approach to keeping the waste out of easy sight is to ensure that the waste pile is some distance below the toilet seat, and that little light is getting in, so that it is hard to see into the toilet and the waste below. This simple design aspect is likely the most important one that makes the toilet most acceptable to new users.

[4] *For example Gisborne District Council in New Zealand has produced a Compost Toilet Guideline (see Appendix V).*

A has to provide several basic functions:

- A place to go to the toilet comfortably;
- Contain the human waste whilst it composts;
- Provide a suitable environment for the composting process to take place;
- Provide easy access to remove the composting waste;
- Not smell unpleasant, and be free from insects and vermin.

All systems require air flow, and will need an air inlet and exhaust, which may be driven by convection, electric fan or solar heat. The general idea is to create a slight negative pressure inside the chamber, so that when you open the toilet lid (which must be closed at all times when not in use) air is sucked down rather than rising up, taking any potential smell downwards with it.

The toilet seat must sit down over the hole with the minimum amount of gap, so that flies and other insects cannot get in under the seat. This is important, as many toilet seats have rubber stops to hold them up a little. If a seat is found to have these stops, take them off, and check that the hinges work so as to put the seat lid right down onto the base. This is a very important point of design.

The simplest method for the exhaust vent - and best in tropical climates - is to have a large diameter plastic pipe, painted black, placed vertically along the sunny side of the toilet, so that the sun warms the pipe, causing the air inside to rise and suck air from below. There needs to be enough ventilation to let air in below, with a mesh screen to keep flies out. A mesh screen should be placed over the top of the pipe to keep any flies out of there too.

Compost toilets should have some drainage for excess liquid, and this can drain to suitable plants next to the toilet. The toilet can have a urine separation facility, and this can drain into those same plants, or be collected into a container for use as soil conditioner. Urine is sterile, not normally containing pathogens, so safe to handle but often smells strong due to the ammonia in it. Citrus fruits such as lemons love urine as a soil conditioner and a banana circle (see Appendix III) placed near to the toilet to take the drain and process the leachate from the toilet is a very effective and sanitary solution.

4

Background to Compost Toilet Use

WATER HAS BEEN USED FOR CENTURIES AS A MEANS TO TAKE AWAY HUMAN EXCRETA, HOWEVER THIS USUALLY RESULTED IN LOCAL WATER POLLUTION.

Urbanisation in the 19th century found many houses supplied with a toilet in an 'outhouse' at the end of the yard, and the back of this facility opened onto an alley between the rows of houses. The human excreta was termed 'night soil' and collected on carts that accessed these backyard outhouses via the alleys behind the houses. As urban development proceeded, reticulated (piped) sewage systems came into being, collecting the waste and using water to flush the waste into a main sewer system, which was collected together into a larger facility for processing. This is the process that exists in most developed country towns and cities today. The modern flushing toilet derives from designs developed in England around 1850. These developments came alongside increasing awareness of the importance to public health of good sanitation practises.

For rural users, open defecation gave way to the use of pit toilets, often called 'Long Drops'. These use a deep hole with a small hut placed on top, and require the hut to be moved periodically as they fill up. These may pollute local ground water, depending on location. Modern requirements where there is no reticulated sewage system involve use of a septic tank, where the toilet is flushed into a large underground tank, and excess water is drained off into the surrounding environment via a drainage field network of pipes. These require periodic pumping out into a tanker truck, with the sludge then pumped into a conventional sewage treatment plant. But the sewage treatment plant option is frequently not available to rural users, and so the sludge from the septic tank may be dumped into uncontrolled landfills, an unpleasant and unsanitary practise. Septic tanks require a largish land area for a drainage field, sufficient for dispersing the excess water from the tank, and a frequent problem in villages and towns is that the local topology is overloaded in this respect, and ground water pollution takes place. In areas where septic tanks are close to fresh and sea water bodies, pollution of these waters is almost inevitable. It is extremely common in the Pacific Islands to find that drainage fields from septic tanks are inadequate for the inputs into the tanks.

Manure from animals has been used as soil conditioner for millennia by farmers, and during the sustainability movement that started in the 1960's, people turned their attention to developing toilets that could use human manure as a soil conditioner in a safe way. Study of the processes of natural breakdown of faeces - and the composting process - found that the potentially dangerous microbes in human manure, the pathogens, would be killed if sufficient heat was provided, and sufficient time was spent in an oxygen-rich environment. Thus the compost toilet was developed, whereby the human manure could be safely contained whist this composting process took place, and the compost resulting could be safely removed at the end and used for soil conditioner if so desired, or at least returned to the natural environment.

SHOWING THE CLOSING OF THE NATURAL PROCESS LOOP WITH COMPOST TOILETS

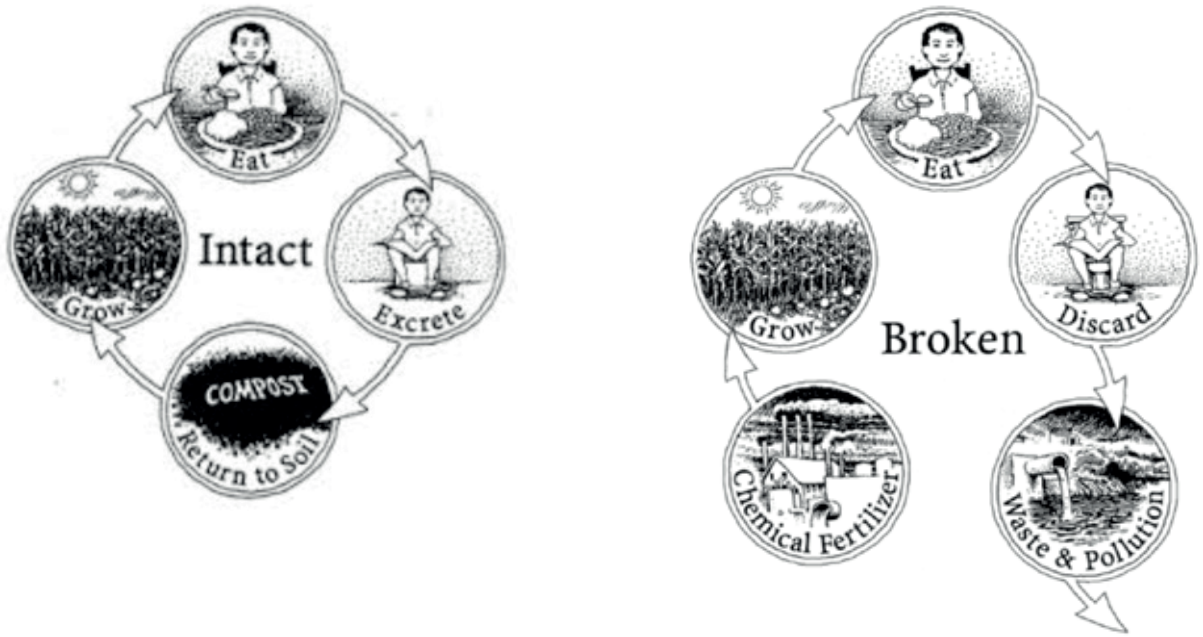

Figure 1: showing the closing of the natural process loop with compost toilets.

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5

Types of Dry Compost Toilet

THERE ARE SEVERAL APPROACHES TO MEETING WCT DESIGN CONDITIONS.

In general, compost toilets fall into two categories: batch type units, where human manure is collected and then left to complete the compost process; and continuous systems, where the manure can be removed fully composted from an outlet of the toilet on a regular basis, whilst the toilet remains in use. Of these two types there are many different variations sold commercially, or self-built based on similar principles. Commercial systems are often designed to be fitted inside houses, and operate in smaller spaces, whilst home built systems tend to be used in rural locations where the toilet 'out house' approach of a small separate building is used.

Which type best suits a particular location is determined by local geography and the preferences of the owner/operator. For all compost toilets, the manner in which they are operated is as least important - or more so - than the design. All compost toilets will require the addition of a high-carbon material, a 'brown' input, to ensure the compost process takes place. This material is called a 'Bulking Agent', and should be readily available locally, be very low cost - ideally free - and have a high surface area to volume ratio. A widely used material is sawdust or wood shavings, being a fine material with a very high carbon content and a high surface area to volume ratio. Other materials that can be used include casuarina needles, and fine leaf litter from the surface of the ground under shrubs. Shredded coconut fibre may also be good.

Ideally, all stand-alone out-house type of toilets, where no piped water supply is available, will have a rainwater tank from the roof so that water can be used for hand washing after using the toilet. It is usually a simple matter to place a small sink for hand-washing inside or outside the toilet, and direct the drain from the sink into the same place that drains any leachate, or urine, from the toilet. It may also be appropriate to add a little water directly into the compost sometimes if the compost pile appears too dry. The moisture level is usually a factor of how many people are using the toilet, as more users usually means that the compost pile stays damper.

5.1 BATCH-TYPE UNITS

Most small composting toilets are of the batch type, and have two or more bins or chambers. The chamber, or bin, is used until it has reached a point at which it is considered full (not necessarily when it is full to the top!). The material is then left alone for the compost process to take place. The semi-composted material can then be moved, after several months or a year, to a secondary composting system to complete the composting process, for example placed into a shallow pit and covered with soil. Such a secondary composting place should be at least 20m from any surface water body, and in a place where rain and flood waters will not wash over the pile and wash the compost away.

Batch type units are themselves of two main types: those that use a removable container to take away the composting manure, often a wheelie bin as used for rubbish collection; and those that contain the compost on-site, inside the chamber, until the process is largely complete.

Double Chamber Batch Type

The double-chamber system is of a batch-type that uses a permanent structure, and is designed to complete the composting process within the chamber. This is the simplest, and usually the cheapest, type of compost toilet to build. It is very effective for four to six people as regular daily users, but for significantly larger numbers the wheelie bin method may be better. Two chambers, typically about a cubic metre each, are used. Each chamber is used for up to a year, or until it is filled, then the other is used whilst the first is left alone to compost. By the time the second chamber is full up, the first can be emptied out, ready for being put back into use again. For higher numbers of users, more than two chambers can be built - or the chambers built significantly larger - the idea being that enough time passes from using all chambers to allow the first to compost to a degree that it has killed all pathogens and nothing recognisable as human waste remains.

Double Chambers typically use concrete blocks to form the chambers, as these are cheap, widely available and will not corrode under the effects of the manure and composting. The blocks also provide a very secure foundation for the floor of the toilet room above. The blocks are arranged so that there are two chambers, and the toilet seat above is used until a chamber is full, which is then left to compost, whilst the other chamber is used. The toilet seat can be built-in above each chamber, or a pedestal can be moved from one chamber to the other as use changes. Typically, a chamber is used for one year at a time, although periods as short as six months can be used, especially in hot climates where the composting is quicker; practical experience will determine this. A family of four should have no problem with a chamber of a cubic metre for a year's use. The arrangement can be seen in figure 2 below.

These simple double chamber designs, using concrete blocks for the chambers and timber for the toilet room, are the most common approach in developing countries. The room on the top of the blocks can be easily constructed using traditional and local materials (for example see figure 9 from Kiribati) requiring overall very little imported inputs, apart from the plastic pipe for the vent and maybe a toilet seat. A commercial or purpose built pedestal can be used, and to keep costs down a single unit can be made movable to fit over either chamber as it is only moved infrequently. Or the pedestals can be built-in to the structure along one side of the toilet.

The floor of the chambers should be a sloping earth floor; an earth floor allows worms to come up into the compost, whilst the slope ensures that any excess liquid drains down to the bottom, where it can drain away into the plants placed next door that will feed off the liquid waste. A Banana Circle next to the toilet (see Appendix III) is a very good option for handling the liquid leachate. A small vent, fitted with a fine mesh to stop flies, is needed to allow air into

the bottom of the chambers. Where local ground water is very close to the surface, such as in an atoll situation, a concrete floor should be used to stop direct leaching of liquid waste into the ground water.

The chambers are emptied via access doors that are placed in one side of each chamber. Appendix I describes how to use the compost toilet, and gives guidelines on emptying the chamber and using the compost.

A shovel can be used to dig the compost out, and using a wheelbarrow or buckets, and placed into a shallow pit, which can be next to the toilet if space allows. The compost material should be covered with a soil layer of at least 100mm, to allow additional composting to take place. With this approach, where each chamber is used for a year at a time, the compost can spend two years composting, one year in the chamber, and one in the pit, before being used as soil conditioner. This way it is almost certain all pathogens and intestinal worm eggs will be dead before the compost is applied to gardens. Figure 8 shows the compost from emptying of a double chamber; the material shown is one year old, and looks like commercial potting mix at this stage.

The chamber should have small sticks placed on the floor before use, and bundles of sticks placed into the upper two corners so as to assist air to move under, around and through the compost. This is important as it is oxygen as well as heat that kills any pathogens. Figure 3 shows this (the black pipe in the photo is part of the urine diversion system of this particular toilet). Some systems use a grid under the compost pile to assist air flow, but these will need cleaning each time the chamber is emptied, whereas small sticks can be dug out with the compost and join the compost pile.

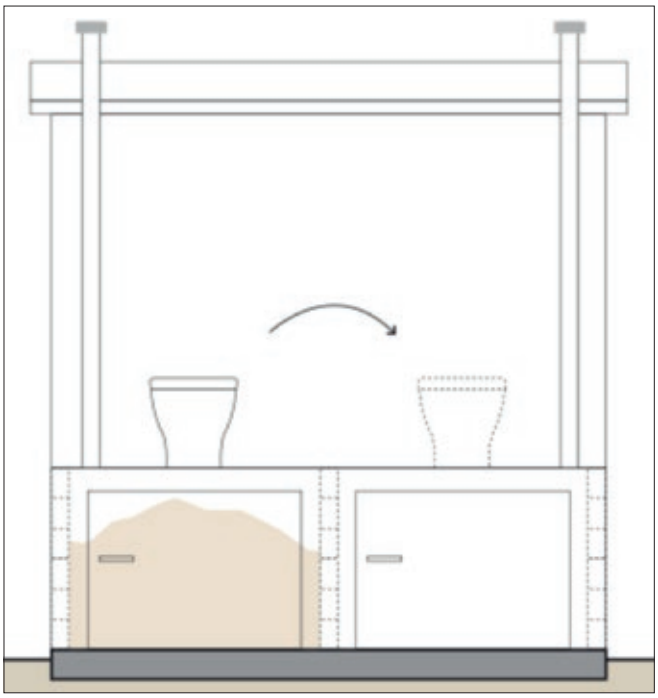


Figure 2: Double Chamber design using concrete blocks

Figure 3: showing sticks placed into the empty chamber to assist air flow.

Wheelie Bin Batch Type

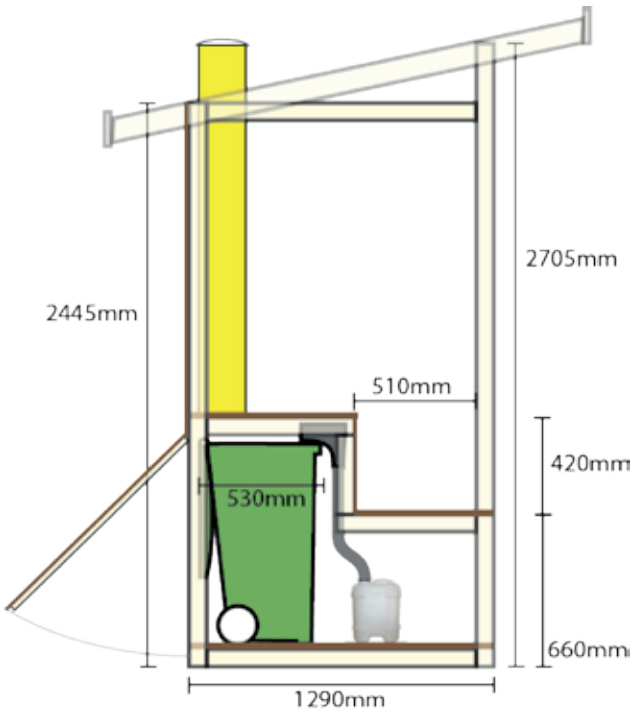


Figure 4 : typical dry toilet design using wheelie bins in a batch process

Where a removable bin is used, these tend to be smaller units due to the difficulty of handling a larger container when full of compost. Wheelie bins - as used for solid waste - are common for this application. 200 litre wheelie bins have the advantage that they hold plenty of compost, but can be quite heavy to handle when full; smaller bins, such as 120 litres, are easier to handle, but need more frequent servicing. Wheelie bins can also be awkward to move over rough ground in rural locations.

The advantage of the wheelie bin is that it has a built in lid, and the material is entirely contained until ready to be tipped out after composting. However, issues can arise around moisture content in wheelie bins: too much liquid and they will be too wet inside at the bottom; drilling holes in the bottom of the bin can help, but may also result in the compost drying out.

Another aspect of the wheelie bin method is that where using larger bins, the toilet seat will be higher above the surrounding ground than with a smaller bin, due to the height of the bin and the need to fit it under the floor of the toilet house. A diagram of a toilet using a wheelie bin is shown at figure 4, where it can be seen that a larger capacity bin will affect the height of the toilet seat.

When one bin is full it must be moved to a suitable place for initial composting and pathogen die-off, which can be six months or more depending on local conditions. The semi-composted material can then be moved to a secondary composting system to complete the composting process, such as a large, flood-proof, compost pile, or a shallow pit at least 20m from ground or surface water. An empty bin replaces the full one and the process is repeated. Smaller bins do not have the under-floor space requirement of continuous systems, which reduces building cost and time to install.

When using wheelie bins it is important to get the air moving through the compost. This can be done by placing a few twigs in the bottom of the bin before filling, and place a bundle of thin sticks vertically into two corners of the bin, so that air can move through the pile. Small holes in the bottom of the bin will assist this aeration process.

5.2 CONTINUOUS COMPOSTING SYSTEMS

Continuous systems have one chamber where all waste is received and stored until composting is completed. These systems include some way for the manure to move incrementally from toilet-end of the system toward the removal-end, sometimes by gravity and sometimes by mechanical action. Accesses for maintenance and compost removal are incorporated into the receptacle unit. A continuous system requires plenty of under-floor space, and is well suited to buildings on hillsides or built on high piles such as is common in some tropical areas. The finished compost is removed, for use after secondary processing. The best known version of the continuous process system is the Clivus Multrum design that uses a sloping floor and gravity to move the compost through the chamber. These have been commercially available for over fifty years.

Other systems may include mechanical pushing bars to move the compost incrementally, or a series of false-floors, stacked vertically, that are mechanically opened at regular intervals to allow compost to drop to the next level, until eventually arriving at the removal section. In general, continuous systems are more complex, may use fans and heaters, and higher cost, but provide a greater capacity relative to space requirements, and are more suitable for inclusion into houses, whereas the batch systems are often used in stand-alone 'out-house' toilet buildings. Most commercial designs use this continuous composting approach. A simple continuous system that uses gravity to move the compost down the chamber is shown in schematic at figure 6. Compost can be removed periodically from the door at the bottom - after a year or two in the chamber - so allowing the material to slowly work its way down the chamber.

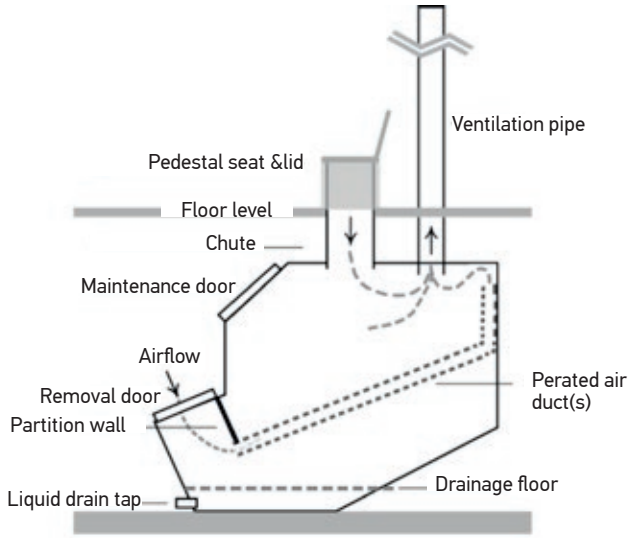


Figure 5: commercial Continuous composting type, Clivis Multrum

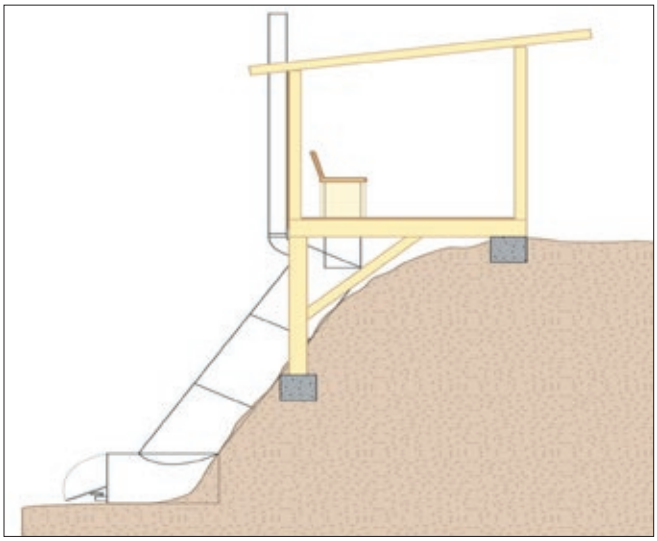


Figure 6: Schematic of a simple home-built continuous composting type of toilet

5.3 URINE DIVERSION SYSTEMS

Urine diverters work well in all compost toilets. Urine is sterile, but as it contains ammonia it is the source of strong smells, especially after a day or so. Inevitably, urine will enter the compost pile, and a little urine is fine, but minimising urine to the pile is a strong point to reducing any odour problems that might arise.

A typical urine catcher fits inside the toilet bowl, at the top front. Figure 7 shows two typical urine diverters, and Appendix II shows details of a urine collection system into a container. The urine caught can be dealt with in two ways: either by collection into a container, typically 20 litres; or else diverted directly onto suitable plants alongside the toilet. Where the urine is collected in a container, this should be emptied daily to avoid the build-up of a strong ammonia smell. Citrus trees like urine, but it can be spread around all types of plants. The important rule is do not tip it in the same place every day, as this will certainly kill any plants over time, and the ground will become quite bare for a long time afterwards. This is a classic example of too much of a good thing. Diluting with water is a very good practise, and the plants will prefer it.

Dilution with water can be easily done automatically by running the drain from any hand basin in the toilet into the urine diversion piping. Where the urine is collected in a container, the hand washing water will also go into the container. Where the urine is going directly from the toilet into plants alongside the building, such as a banana circle, the basin water will dilute the urine and benefit the plants.

If the toilet is used for all urination, rather than for only defecation and associated urination, the urine collection system using a container is advisable, as too much urine into the banana circle is not good. For most rural and outer island people, normal practise is to urinate into the local vegetation, so this is not a problem. It is good practise to put a litre of water or so down the urine catcher after each use; this will prevent the build-up of urine salts in the piping, minimise smell, and keep the urine system clean. Place a jug next to the wash basin and fill and use in this way after each toilet use.

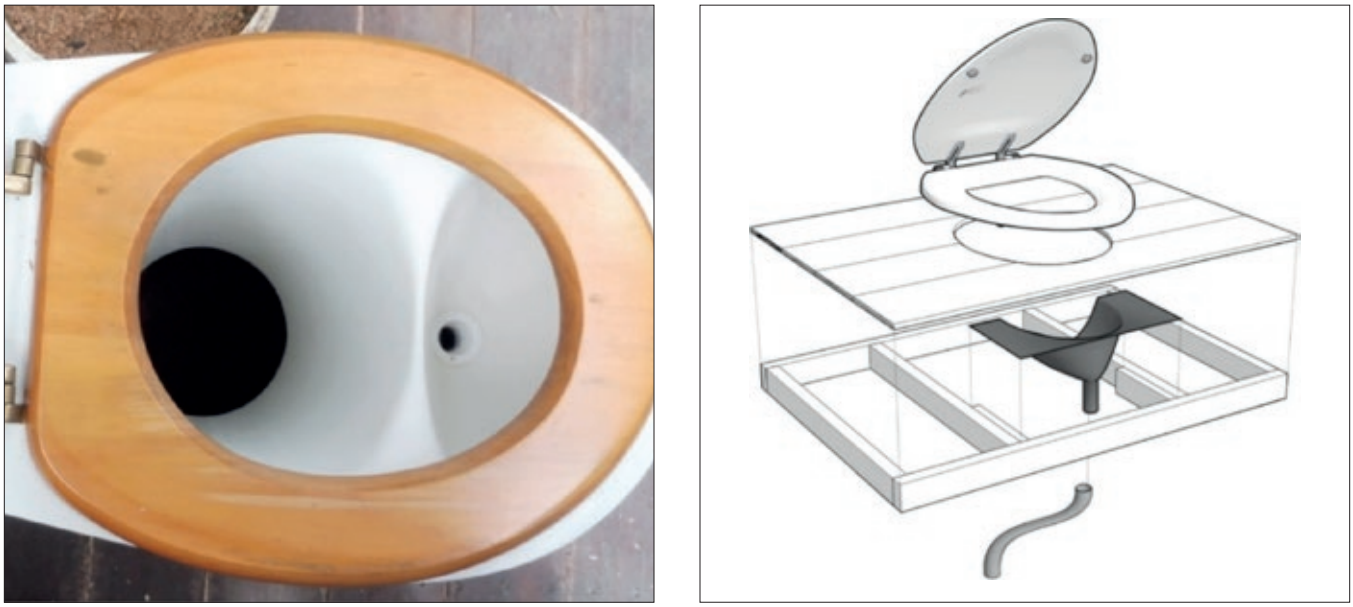


Figure 7: one example of built in urine diverter, and a second showing an addition.

6

Environmental impact of Compost Toilets

COMPOST TOILETS, WHEN PROPERLY MANAGED, HAVE ONLY POSITIVE ENVIRONMENTAL IMPACTS[5].

This is because a correctly built and operated compost toilet can contain and process human excreta into a safe and valuable resource, with no ground or water pollution and relatively low carbon-dioxide outputs. Environmental impacts include:

- **Reducing demand on water resources** as typical flush toilets can use over 10 litres per flush;
- **Reducing pollution into water resources** and water habitat as there is little excess liquid to have to manage, unlike conventional flushing toilets using septic tanks;
- **Reducing energy consumption** in pumped water supply and sewerage processing systems;
- **Reducing use of external fertiliser** inputs;
- **Increasing soil fertility** through returning human waste and its nutrients to the ecosystem for recycling.

Overall, as compost toilets do not require flushing, they save many thousands of litres per year per person, of the order of 20,000 litres. This benefit reduces the burden on water resources, infrastructure, and waste water management. In the Pacific Islands this is of particular importance due to minimal water resources in low-lying islands and minimal infrastructure in some areas. If leachate in the system is effectively contained or bio-filtered, then pollution of local water resources is non-existent compared to septic tanks.

6.1 REDUCED DEMAND ON WATER RESOURCES

The 'flush toilet' became the standard throughout the developed world in the early 20th century, and today it is the largest consumer of potable water in the home. According to the Environment Protection Agency in the US, one person will use about 28,000 litres of potable water per year with a typical flush toilet[6], which is 76 litres per day. The average residential consumption of water in North America is 350 litres per person per day[7] and so the flush toilet uses more than 20% of residential water in North America.

In the Pacific Islands, water resources are a growing issue. In many places good potable water is in short supply, especially during increasing El Niño induced droughts. In rural areas, water is often provided from rain water collection systems. During times of drought, houses supplied by rainwater can run out of water significantly faster when the house is using a flush toilet system, and town water supply systems are put under unnecessary extra demand. Dry, composting toilets can have a very significant impact on household water demand.

[5] *This section draws on published recent research into the impacts of compost toilets, details in the references at Appendix V.*
[6] *(Balzer, 2012, p. 11),*
[7] *(W.W.C., 2016),*

Where a communal supply is used for a village, fed by a small dam from local water sources, the demand from flush toilets can be the difference between making it through a drought and not.
In an atoll situation, where water is always an issue unless it is raining, the problems are amplified, and compost toilets are potentially of great advantage in reducing water consumption during dry periods.

6.2 POLLUTION FROM SEPTIC TANKS

In many Pacific locations, the construction and operation of septic tanks is crude. Septic tanks are often not big enough to process the inputs, and the drainage fields attached to the tanks do not cover the required area needed to ensure that the excess liquid can be properly processed by the natural environment. With many modern houses built near bodies of water, both sea and freshwater, pollution by septic tanks is a major cause of excess nutrients in rivers and shallow lagoons where water retention periods are not fast enough for proper flushing. The effect of this pollution is usually seen through nutrient build-up in coastal waters which may show increased weed and algae growth as a result, to the detriment of the normal coral reef ecology, which thrives in a low nutrient environment. In an atoll environment, the problems are amplified as the sandy soil easily drains into the lagoon, with most houses being situated lagoon-side.

6.3 POTENTIAL FOR GROUNDWATER CONTAMINATION

As compost toilets use very little - or no - liquid, the potential for groundwater contamination is low. Some types of composting toilet will generate a little liquid which will need draining from the chamber; commercial designed units usually have methods, such as forced ventilation and heating, to avoid liquid build-up. The amount of liquid is very dependant on the amount of urine going into the toilet. Whilst a typical toilet will withstand some urine, if the toilet is to be used for urine regularly by all the users then it is best to use a urine diversion system, as noted above.

To avoid any chance of ground water pollution, the toilet should be situated away from a water body, and arranged so that the path of drainage is into a plant-based treatment bed. These plants will need to be urine tolerant and prefer a damp environment.

A Banana Circle, where a pit is dug, lined with cardboard, filed with organic matter, and planted with Bananas around the edge is an excellent way to process any excess liquid. The Bananas will soak up any liquid and the compost heap in the middle of the Bananas will act as part of the processing and filter system. Appendix III shows how to construct a Banana circle. Papaya can also be used in place of Bananas, but do not mix Bananas and Papayas together as one will kill the other. Lemon and some other citrus trees are also very happy to have regular access to urine. The amount of liquid coming out of a compost toilet is usually very small, if properly used, and there will be no obvious stream of liquid visible, unlike a septic tank with poor drainage characteristics which may have an obviously wet aspect around its drainage field.

6.4 USE OF COMPOSTED MATERIALS

Good quality compost from a dry toilet will be black or very dark brown, be reasonably dry, friable, will not smell, have nothing in it that looks like faecal matter, and look very much like commercial potting mix. Anything that looks wet or light in colour will definitely need more composting, and should be handled very carefully and treated as unsanitary. Figure 8 shows the material from a double chamber.

The most appropriate and beneficial use of composted material from toilets is as soil conditioner for the growing of plants. The compost can be used in the same way as other horticultural compost, and the purposes and methods of application is common knowledge among gardeners and horticulturalists, especially ‘organic’ growers. When compost is applied as a soil conditioner it helps create the perfect soil environment for food crops, increasing nutrients for plant growth and health, and increasing the nutrient value of the food product. It is environmentally beneficial, not only by recycling organic material that would otherwise be dumped, but also improving the ecological properties of the soil to retain water and nutrients.

Typical uses for compost from dry toilets are around fruit trees, and mixing in with other sources of compost as an 'activator' to garden compost heaps. The compost is good for planting any type of tree, shrubs and flowers.

At its simplest, the compost can be dug into new gardens prior to planting, mixing in with the soil and other sources of compost. Depending on local culture and law the humus may not be permitted to be used on certain types of crops. In New Zealand it is not permitted to use compost from dry toilets on certified organic commercial food crops (food crops that will be sold to the public as 'certified organic'). However, city sewerage sludge has been composted and is permitted to be sold commercially as garden compost in New Zealand. For cultural reasons it is recommended to avoid using compost from dry toilets directly on vegetable crops, and to practice hygiene and sensible timing when applying the compost to the roots of fruit crops. Always wash your hands after handling compost and manure of any type, and use gloves too.

The amount of compost that a year's use by four people will make is not great once it has sat, composting, for another year before use, such as when using the double chamber system. The material breaks down to a large degree, and may end up less than half of the volume that appeared to be in the chamber at the end of a year's use.

Figure 8: Compost dug from a chamber after one year's composting

7

Avoiding Pathogen Contamination

All known pathogens will die outside the human body within two years[8]. In tropical climates this may well be shortened as heat is a factor in killing pathogens, and the compost will be hotter in tropical areas due to much higher ambient temperatures.

A natural soil or water environment provides for the best survival rates of pathogens potentially found in human waste. The eggs of intestinal worms are the most resilient, particularly Roundworm, which is adapted to survive in soil for up to 2.5 years. Except for intestinal worm eggs, all other known pathogens will very probably die within three-months cold compost toilet conditions, certainly in tropical regions. In thermophilic, or hot composting conditions all pathogens die quickly[9]. The Salmonellae group of pathogens, including typhoid, will die within one day in hot composting conditions, but will survive up to one year in natural soil conditions, without composting. Thus compost toilets are much safer than open defecation or use of pit toilets that are not designed to compost.

7.1 PROCESSING FOR GOOD SANITATION

There are several key points to consider around processing the compost so that it can be considered sanitary. However, anyone handling compost from toilets should assume that it is potentially unsanitary, and take suitable precautions such as gloves and good washing of hands and clothes after handling the compost.

Time: Two years in composting conditions can be expected eliminate all pathogens, including Roundworm, especially in the Pacific Islands. A year is sufficient for other pathogens. If the compost is not able to mature this long within the toilet receptacle, then a secondary composting process can be used.

Secondary Processing: When the compost is around six months mature (depending on whether there have been aerobic or anaerobic conditions and temperature), it is safe to handle with the practice of hygiene such as dedicated tools, clothing, and washing hands. The longer the compost remains in the toilet the better. The compost can then be moved from the toilet receptacle to another composting location, such as a compost pile, ensuring there will be no run-off, rodent access, or public access (especially children). The compost pile can be covered with a layer of soil or other garden compost to stop flying insects, and left to mature.

[8] As is indicated in Table 7.14 from the Humanure Handbook, (included in the References, Appendix V),
[9] See References in Appendix V.

Hot Composting: Much like how animal manure is treated in horticulture, a new compost pile can be made by mixing the semi-mature compost from the dry toilet with fresh nitrogenous and carboniferous plant material. When done correctly this secondary compost pile will reach temperatures high enough to eliminate all potential pathogens. This approach can shorten the time before safe use of the compost material.

Testing: Where periodical testing for Roundworm or other prevalent pathogens is carried out, this will provide a useful indication of the success of the composting toilet and secondary composting system used.

Hygiene: Ensure cleanliness of bodies, tools, and clothing that comes in contact with non-matured human manure to avoid transfer from the contained site to the public environment.

7.2 APPLICATION METHODS

Do not apply compost from dry toilets directly to vegetable crops. By not using this compost on vegetable crops any potential risk of food contamination is avoided. Timing of application is important: apply to tree crops at times of year when there will be the least number of workers or visitors around the trees, and no fruit harvesting. In this way there will be additional time for pathogens to die-off before harvest or other work periods.

Ground cover applications: apply when preparing the ground prior to planting. After the compost has been spread, cover it with mulch to avoid the possibility of the compost drying to dust and being carried by the wind. It is best if the compost is dug into the ground; the compost should be spread out evenly and thinly, and mixed in with the topsoil for 50 - 100mm, not too deep. To avoid any possibility of food contamination, do not use where the ground is being prepared for root crops. However, if the compost has fully matured for the full duration of over three years, then all potential pathogens will have died and the compost will be safe to handle and use for any kind of agriculture.

8

Regulations and Standards

AUSTRALIA AND NEW ZEALAND HAVE A JOINT STANDARD, AS/NZS 1546.2 - 2008, FOR CONSTRUCTION AND OPERATION OF DRY TOILETS, CALLED WATERLESS COMPOSTING TOILETS (WCT).

Australia and New Zealand have a joint standard, AS/NZS 1546.2 - 2008, for construction and operation of dry toilets, called Waterless Composting Toilets (WCT). This standard can only be obtained by purchase from Standards Australia or Standards New Zealand, national government bodies, is subject to strict copyright controls, and as such cannot be reproduced here. The Standard is primarily aimed at those manufacturers who build commercial compost toilets, and to assist local government planners to evaluate applications for new-build compost toilets.

The existence of a government approved standard for compost toilets clearly shows that the construction and use of compost toilets is widespread in New Zealand and Australia. Where compost toilets are integrated into houses and other buildings, the various building codes also provide rules. Local government requirements vary from district to district, but are largely dependant on the local authority's staff experience with compost toilets.

The Standard contains provisions dealing with the following matters:

- performance requirements;
- design factors (public health; construction; composting requirements);
- end product quality;
- sampling end product;
- operation & maintenance;
- safe handling of end products.

The standards are voluntary, and their use in Australia and New Zealand varies greatly among local authorities. The Standards are voluntary because they are not specifically referred to in any legislation. Some Standards are a legal requirement because legislation specifically refers to them, for example electrical wiring standards. But the existence of an AS/NZS Standard does mean that it is very difficult for local government to arbitrarily deny a building permit that includes a compost toilet, a situation that did occur in the past where local government staff might simply consider WTC unsanitary simply through their own ignorance. The Standard provides all the information local government planners and building departments need to ensure that any compost toilet built is, in fact, sanitary and sound.

Some local territorial authorities refer to the published standards, whilst some have their own guidelines. Some regional authorities do have 'permitted activity' rules for compost toilets in their region, which then institutionalises the use of WTC as part of the local District Plans that each local government must produce at ten-year intervals. For example the Wellington and Canterbury regions have 'Permitted Activity' rules for compost toilets, where the issue about an individual application to build a toilet is simply around whether it conforms to the Standards.

The standard covers performance statements, evaluation tests and basic testing requirements for toilet units, plus guidelines for safe operation and basic health requirements. The performance criteria are straightforward statements of requirements for compost toilets, covering public health, environmental contamination and construction. General design guidelines are provided for these performance requirements, and for installation and operation instructions. The standard appendices describe some normative testing that can be conducted, and provide some information to assist designers.

Under the New Zealand building regulations, a domestic dwelling must have a certified toilet, and where there is a sewer system connection for a property (something that is usually only in urban areas) then the drainage system, including any water flush toilet, must be connected to it. In rural areas compost toilets can be used as the dwelling toilet, and a suitably qualified professional engineer can sign off designs of such toilets, through a 'Producer Statement'. In most cases today, compost toilets are permitted on a case by case basis as part of the building permitting processes.

An example of local authority acceptance in New Zealand is provided by the Gisborne District Council, regulations and guidelines for compost toilets in their guidelines for waste water management[10]. Gisborne is on the east cost of the North Island of New Zealand, and covers a large rural area that has many remote Maori communities.

The Gisborne Council document covers the subjects detailed in this report, but in less detail, but also includes a section 5 'Regulation' which includes the relevant building regulations, the Standard, specific requirements of Gisborne Council, and sub-sections covering the sale of the property. The subsection regarding the building regulations states: "Building Act 2004 (Part 2, section 67) enables the building consent authority to grant a waiver or modification of the building code subject to appropriate conditions. Most modern commercial composting toilet systems, when used and operated within these guidelines, can readily achieve the personal hygiene requirements envisaged under Clause G1, and hence can be consented for installation and use within a dwelling".

The specific conditions required by Gisborne Council include that the building site (for new buildings) should be able to accommodate a conventional septic system should the compost toilet system not work properly, and if a subsequent owner should decide they want to install a WC. This includes a requirement to "re-commission' the WCT for any new owner (essentially make sure that you give them a clean toilet to start with).

The other specific conditions are very general, except "...all consent applications should include a statement regarding the extent to which the proposed system meets the compliance requirements of the Standard. This shall be compiled by a person recognised as having authority in such matters."

The Gisborne Council document allows for both commercial systems and home built systems, as long as they meet the requirements of operation and use of the compost. Half of the document is an appendix that provides details of commercial systems available on the market in New Zealand. A full reference supplied in Appendix V.

[10] *Guidelines for On-site Wastewater Management (2012), section 4.14 Composting Toilet Systems, pp. 48-52. (See Appendix V)*

9

Use of Compost Toilets in the Pacific Islands

WATERLESS COMPOST TOILETS HAVE NOT BEEN WIDELY USED IN THE PACIFIC ISLANDS, AND THERE ARE VARIOUS REASONS FOR THIS.

But there have been attempts to introduce them by development agencies, and some have been successful. A common challenge is to find a suitable and easily accessible, cheap bulking agent of a high carbon material to add to the compost pile after each deposit. The material used in countries such as Australia and New Zealand is usually sawdust, and a typical NZ rural home will produce sufficient sawdust for their compost toilet simply from normal firewood preparation. However, small, broken, dry leaf litter from under bushes is an excellent bulking agent for compost toilets, and usually readily available even on atolls. As only a single handfull of bulking agent is required per use, a 20 litre bucket of bulking agent will last quite some time. There is no advantage at all in using too much bulking agent, in fact this prevents better composting. Often too much bulking agent is used in an attempt to cover the human waste from sight, but the best approach to this is to ensure that the waste pile is some distance below the toilet seat, and that little light is getting in, so that it is hard to see into the toilet. Designs used in the Pacific have frequently neglected this aspect; use of a pedestal with a round hole at the lower end, rather than a toilet seat placed onto a box, restrict light into the chamber below, and as a result users find it far easier to use as they don't feel like they are sitting on top of someone else's business. This feeling is the frequent reason that too much bulking agent is used, causing a poor composting process, drying out of the pile, and more effort to source and refill the bulking agent container. Lack of bulking agent will result in a smelly, wet toilet, which is, naturally, unpleasant to use, as well as not composting properly. If nothing else is available, cooking fire ash can be used; it is not ideal, and will slow down the composting, but much better than nothing.

The high ambient temperature of most Pacific Islands means that the destruction of pathogens is much faster in the Pacific than in temperate climates, and the tendency can be for the compost to dry out too fast rather than being too wet, although too wet can be a problem where design is poor and use rates are high.

9.1 EXAMPLES OF COMPOST TOILETS IN THE PACIFIC ISLANDS

TUVALU

The GEF Pacific Ingenerated Water Resource Management Project (IWRM) built 40 compost toilets on Funafuti Atoll in Tuvalu in 2011 - 2012, primarily aimed at water use reduction and coastal waters pollution prevention. Funafuti is the capital of Tuvalu, and has the highest population densities in the country. These units were a double chamber type. A video was made[11] showing the entire process of construction, operation and the rationale for the activity. Information requested from Tuvalu and SPC.

MARSHALL ISLANDS

IWRM replicated the Tuvalu method at a site in the Marshall Islands, in Laura village on Majuro Atoll. Further information has been requested from the project manager, who is currently working at the Republic of the Marshall islands Environmental Protection Authority.

KIRIBATI

The Foundation for the Peoples of the South Pacific Kiribati (FSPK) had two compost toilets constructed around 2000 on South Tarawa atoll, Kiribati. These were of the double chamber design, but the units did not work well, in that the chambers were too small, very quickly filling up with waste and the waste pile being too close to the seat; there was no active drainage of excess liquid, resulting in a compost pile that was too wet; and the use of green leaves as the bulking agent, which should have been 'brown' and a high carbon material. These factors added to excess liquid, putrefaction and general lack of composting process. FSPK had a staff of around 15 people at that time, and so usage was high, adding to the dampness problem. The system lasted about two years, but the wet conditions resulted in a smelly toilet. FSPK had gardens growing fruit and vegetables, so there was a ready use for the compost, but it required secondary composting before it could be used. As a result, the toilets were abandoned completely after about three years.

Another trial of a compost toilet was conducted in Kiribati during 2004 - 2007. This involved use a proprietary 'Rota Loo' from Australia which uses a batch process method, with baskets hanging from a circular frame which is periodically turned as the baskets are filled up. Once all baskets are full, the first is removed, emptied and replaced empty. This system used the needles from Casuarina trees as a Bulking Agent - abundant at the toilet site in the Materials Recovery Facility in Betio, Tarawa. This toilet used a concrete block base with a local built top half for the room, see figure 9. This toilet suffered from rats getting into the chamber around the access door, and they chewed the baskets to get at the compost. The floor of the chamber had a drain into a banana circle that was built next to the toilet, and a small water tank added (neither shown in the picture). However, the tropical heat of Kiribati dried out the compost faster then it would do so in southern Australia, where the Rota-Loo is designed and mostly used, resulting in poorer composting. But aeration was good with the bags, so pathogen destruction given the air and temperature was assured. The frame and bags had to be imported from Australia, and included the pedestal; as such, this option was not ideal for a Pacific location and wider replication. Another factor was that the bags/baskets that held the compost required manual removal, and this was not done regularly enough. Whereas with a double chamber system, compost removal is easily done with a shovel only, keeping the operator well away from the compost.

[11] *http://www.pacific-iwrm.org/Tuvalu-ECOSAN.html*

Figure 9: the compost toilet in the recycling yard at Tarawa, Kiribati.

Appendix

How to use a Compost Toilet

THIS GUIDE GIVES THE SIMPLE POINTS TO OPERATING YOUR COMPOST TOILET SUCCESSFULLY. IT ASSUMES THAT THE TOILET DESIGN IS GOOD AND THAT THE TOILET IS WELL BUILT, AND THESE NOTES BEST APPLY TO A DOUBLE CHAMBER SYSTEM.

There are three main rules:

- Keep the toilet seat down and shut at all times except when using the toilet.
- One handful of Bulking Agent is enough for each use.
- A little bit of water is OK for cleaning the bowl, but too much urine will make your toilet smell.

HEALTH CARE

Always wash your hands after handling the compost or compost containers, even if you didn't touch the compost, just to be safe. The disease-causing microbes are called pathogens. All pathogens - except round-worm eggs, if they are present - will be killed by a good compost toilet within 2-3 months, especially in tropical places. But it is a good idea to assume there is always potential for you to get exposed to pathogens when handling human compost, so take care to be safe.

BULKING AGENT

This is the carbon material that you add to the compost pile each time it is used to get the right mix of nitrogen and carbon for good composting.

Don't use too much, as too much will dry out the compost pile. A single handful or cup full is usually fine. The Bulking Agent is not used to cover the compost pile completely so you cannot see anything else. If you do this each time, you will use far too much Bulking Agent and upset the compost process.

Put the Bulking Agent into a bucket next to the toilet seat. A 20 litre bucket will last a long time, depending on how many users, at one handful per use.

The Bulking Agent must be very small pieces of dry, woody plant material. Sawdust works well: if you cut your own firewood with a saw you will probably make enough for your household from that. The fine leaf litter from under bushes can be very good (pull out the twigs as you collect - just scrape it up of the ground by hand).Casuarina needles work well, pine needles are a bit too coarse. Coconut fibre will work if it is pulled out into fibres and loose. Cooking fire ashes will be better than nothing, but will slow down the microbial activity; don't use too much! But wood ashes will help cut down smell if that becomes a problem. Do not use treated timber sawdust or you will be introducing toxins into your compost pile.

TOILET SEAT

The Toilet Seat and cover must sit well down so that there are no gaps under the seat to let air out and flies in. Keep it down at all times except when in use. The idea is that as the air is being slowly sucked up the vent chimney of the toilet, and when you open the lid the air gets sucked down into the toilet, instead of a toilet smell coming up at you! Make sure you seat and cover fits down well. If you are using a home built toilet pedestal, you can use a plywood cover that fits under the toilet seat to close the toilet off.

VENTS

Air flow is really important to make sure the compost process is working and killing any dangerous bugs, but also to give you a nice toilet that doesn't smell. There should be a small air intake vent at the bottom of the chamber somewhere, and then a chimney pipe (which should be painted black) that takes air out. The black pipe needs to be in the sunshine as much as possible, so then it heats up, and as hot air rises, the air flows out of the top and sucks air out of the toilet chamber below. The pipe should end 300mm or so above the roof, and have a wire mesh to stop flies getting down. Make sure the pipe is not shaded by plants around it, and also that the wire mesh is not blocked by dead leaves over time. If there is a vent you can see down below, make sure it is clear and not overgrown (it should have wire meshtoo, to keep insects out).

EMPTYING THE CHAMBER

After a chamber has been left unused for at least 6 months, dig out the chamber with a shovel and use a wheel barrow or buckets to take it to a shallow pit where you can cover it with a thin layer of soil (50-100mm) and let it sit for another year or so, for secondary processing. After two years you can use the compost around the garden. You can put the pit next to the toilet so that you shovel it straight into the pit, if space allows. The compost should be dark, not smell, be a little damp but in no way wet. You should not be able to see anything that looks like human faeces, if you can, the toilet is not working right, but this would be very unusual.

Use gloves when working with the compost, and wash your hands afterwards. The longer the compost pile is in the chamber undisturbed, then better. A year in the chamber before digging it out is very good. If you arrange things right you can work the emptying time so that the final compost is ready for your garden at the right time of year to apply to the plants and trees. Do not put the compost directly on vegetable crops. You can mix it with soil when preparing the ground for vegetable crops, before planting. Around fruit trees is good. Around garden flowers and shrubs is good. Into a garden compost heap is also a good use as it will help make that heap work better.

Seat down (and sawdust bucket at left)

or seat up with a cover plate in place.

There is no need to get every last bit of compost out of the chamber when digging it out. Leaving a little compost behind will help start of the composting process when the chamber gets reused. Once you have dug out the chamber, place a few small sticks into the bottom of the chamber; these act to help air get into the compost pile. A bundle of sticks in each back corner helps with air movement too. Make sure that any drain that runs out of the chamber, to take away excess liquid, is clear when you are making the chamber ready for another round of use.

ROTATING CHAMBER USE

Don't use a chamber until it is full right to the top. If a pyramid pile is developing, use a stick to push the pile down and flatter. If the chambers are filling up fast, then the chamber is too small for the number of users. Build more toilets with bigger chambers. If you are using Wheelie Bins for compost chambers, then the wheelie bin replacement is the same as a chamber rotation.

For Double Chambers, rotate use once a year even if the chamber is not full. This gives a good rotation time, and one year composting in the chamber.

WASH BASIN

Have a wash basin, or at least a tap, in the toilet or next to it, for washing hands after use, just like any toilet. Washing hands after using the toilet is the most important way to reduce the chance of spreading intestinal diseases. If possible, run the wash basin water into any urine catcher pipework, or else onto suitable plants - like bananas - next to the toilet, to avoid a messy wet patch. Make sure there is soap at the wash basin. A little water may be used to clean the toilet bowl when needed. If using a tap for washing that runs straight onto the ground, with no basin, put some stones under the tap to help disperse the water and stop a muddy patch forming.

Water can be obtained from rain off the roof off the toilet, using a gutter and a small tank. The toilet roof is built using traditional materials, just a small piece of roofing iron laid on top of the traditional materials of the roof might give enough water to fill an old oil drum or other tank for hand washing water. A little water in a jug, along with a toilet brush, is useful for cleaning the toilet bowl sometimes.

Sticks on the floor and back of chamber to help with air flow

URINE CATCHER

If using a urine catcher system, pour about a litre of water down the urine catcher after each use. A jug by the wash basin is ideal for this and easy to fill. This will keep the pipe clean and stop smells, and also salt build-up which can block the urine pipe over time. Run the urine either into a container and put it around trees - especially citrus trees - or run it down into a banana circle. The extra water from flushing the pipe helps dilute the urine going onto the plants, as urine can be strong fertiliser. Urine is normally sterile, but wash your hands after handling the container.

COMMERCIAL TOILET CLEANING PRODUCTS

Do Not use commercial chemical cleaners for toilet to clean the toilet. These products will likely kill the microbes in the compost pile that make the whole thing work. Use bar soap and a toilet brush for cleaning, or products that clearly say they are safe for septic tanks. Do Not use Bleach. Only use cleaners when you really need to, not on a daily basis. There is a product called 'EM' - Effective Micro-organisms - that will help the microbes in the compost toilet. Putting some of that down regularly will help the compost process. It is used diluted with lots of water. Using a hand spray bottle, and giving a small squirt regularly down into the pile is all that is needed.

TROUBLE SHOOTING

The two main troubles are smells, and invasion by a certain type of fly. Smells indicate poor operation. The flies get inside sometimes, that is nature!

Smells: these are caused by three things: bad ventilation; compost pile too wet; or compost pile not working properly. The most common problem is that there is too much urine going into the compost. If the toilet seat cover is left up regularly, will make the toilet smell as this disrupts the ventilation system. Sometimes, the toilet smells so people leave the seat and cover up trying to get rid of the smell, but this tends to make it worse! Too much Bulking Agent after each use will make the compost pile too dry, so the process does not work, and this may make the toilet smelly.

- Check that the vents are clear, as noted above.
- Check if someone in the household is using the toilet for all urination but there is no urine catcher or if there is a urine catcher but they are not peeing into it but straight onto the pile.
- Check that the seat and cover is being put down all the time.
- If the compost pile looks too wet, put a good thick layer of bulking agent over the pile, and work out why it is too wet.
- Check that there is enough bulking agent always in the toilet for each use. If the bulking agent is not used, the toilet will be too wet and the compost process will not work. Make sure someone is responsible to keep the bucket of bulking agent topped up. If the Bulking Agent is not there, people cannot add it to the compost after use, and the toilet will definitely then smell.

Fly Invasion: Sometimes you find lots of black flies coming out of the toilet when you lift the seat. Somehow, a fly got in and laid a lot of eggs. These flies are usually black flies that look like large mosquitoes (but they are not), they are not houseflies. All you can do is try and kill off the invasion. There are two simple methods: tip a good dose of fireplace wood ash down the toilet, making sure the pile is completely covered. The other thing you can use is gardener's lime, or else very fine coral sand - coral dust - which is also lime. Mineral sand will probably not work. Both of these will stop the flies, but they do upset the compost process a bit, so you have to bear that in mind. Don't put ashes or lime down the toilet regularly to stop flies before they come, as this will kill off the good microbes you need to do the composting. Best to only do so when you have a fly problem. Usually you can get the problem sorted out quickly when you notice the first few flies appearing. They will sit under the seat, in the bowl, and wait for the lid to open so they can fly out. They do not bite, so don't worry about being bitten or stung whilst sitting in the seat!

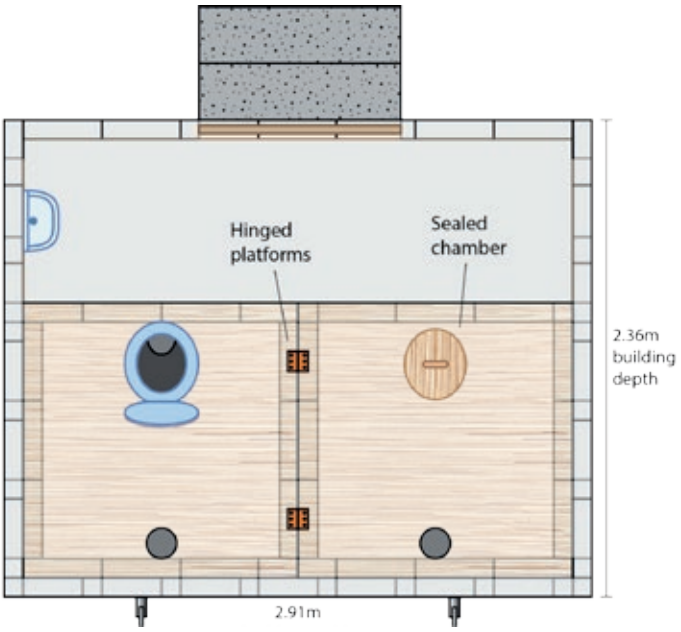
Uncomposted Items

Do not put anything other than human waste or toilet paper down the compost toilet! Sanitary pads, disposable diapers, cardboard, condoms or anything else should not be put down there! It will not compost! You will be digging it out again later! Put them into the rubbish.

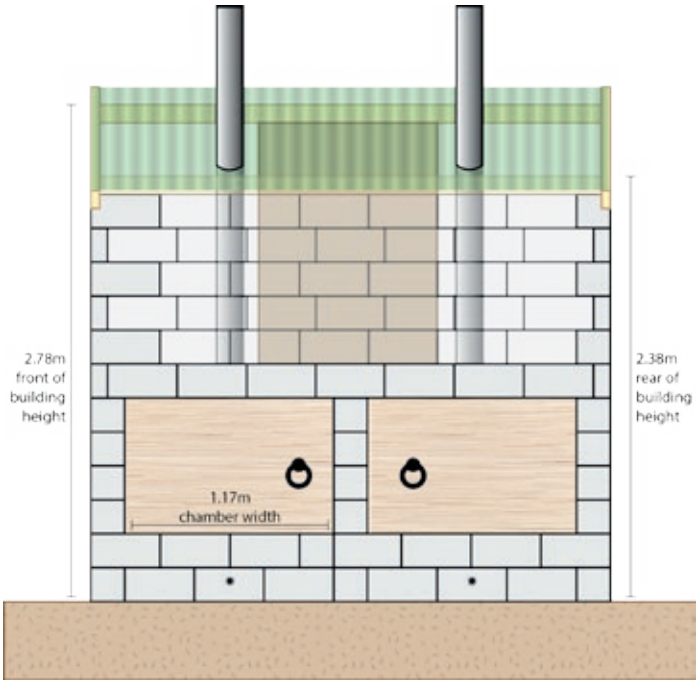
II

Construction
Drawings of Dry Toilet Types

DOUBLE CHAMBER

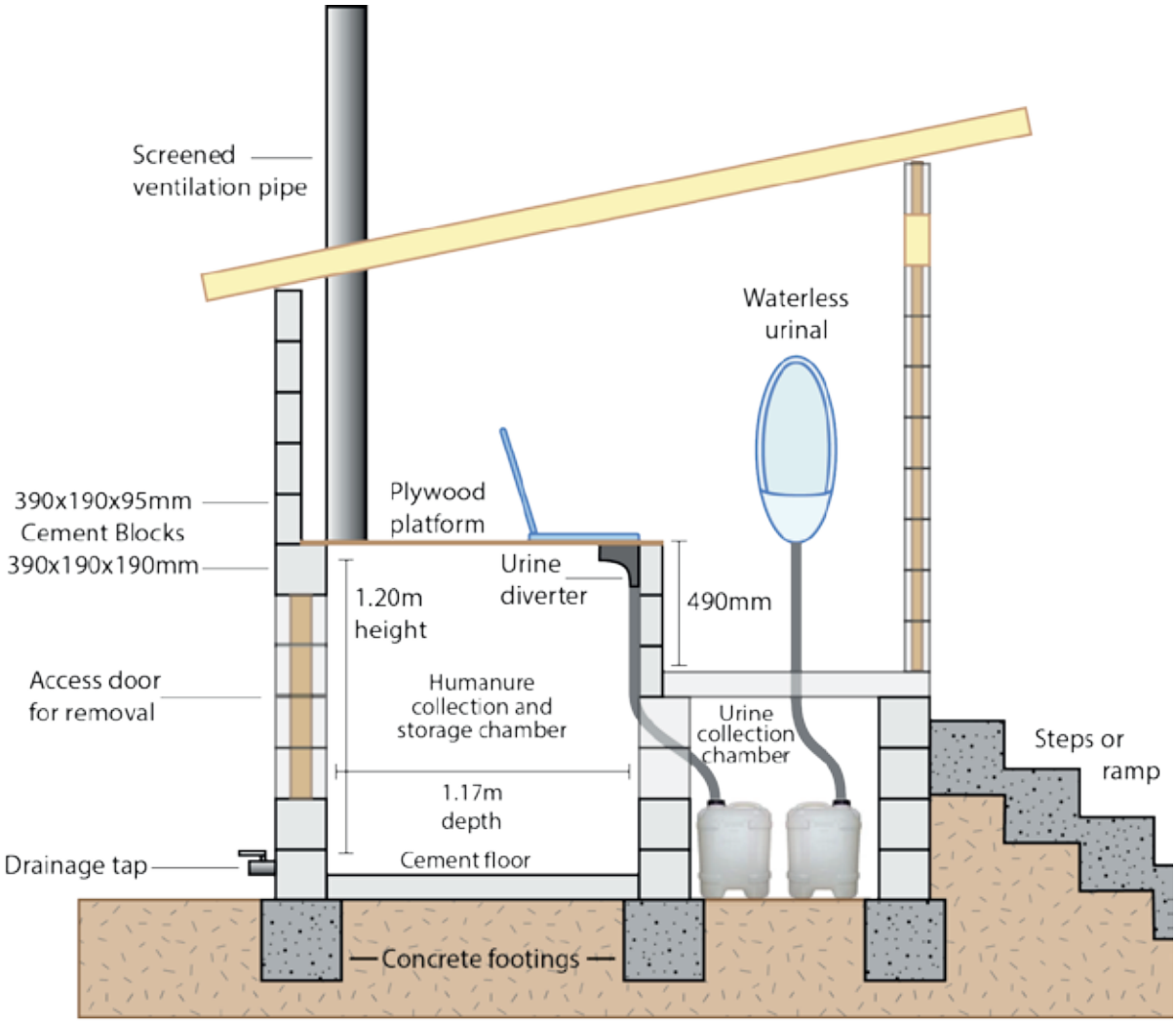


Plan View:
Showing a toilet pedestal that is moved across as required.



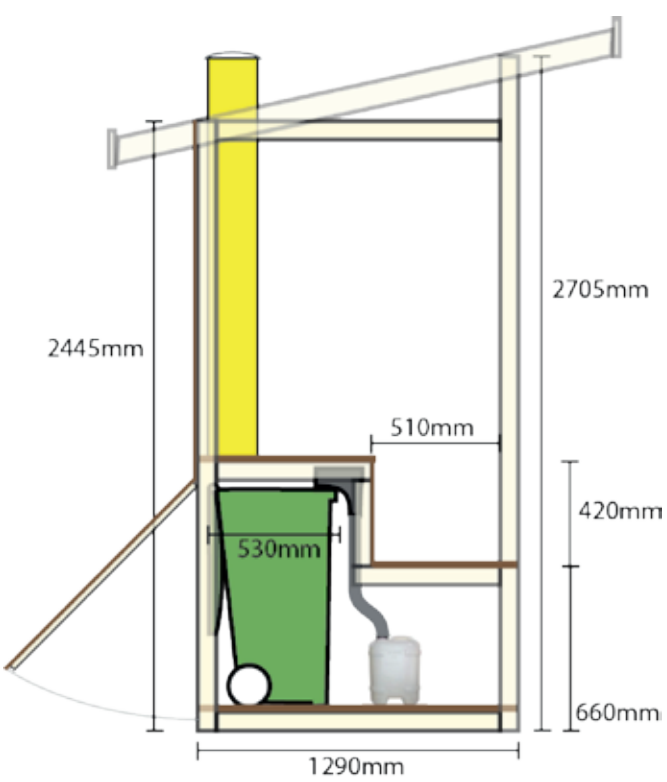
Back view:
showing hatches for removal of compost

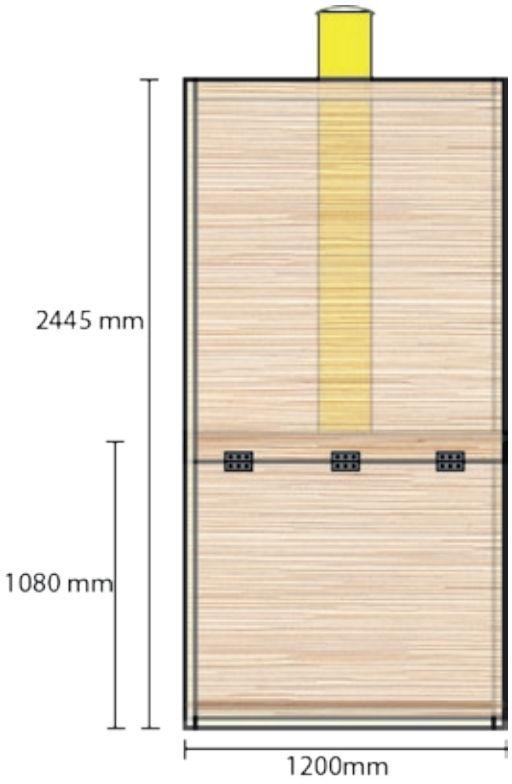
DOUBLE CHAMBER



Side View:
also showing urine collection system if desired

WHEELIE BIN



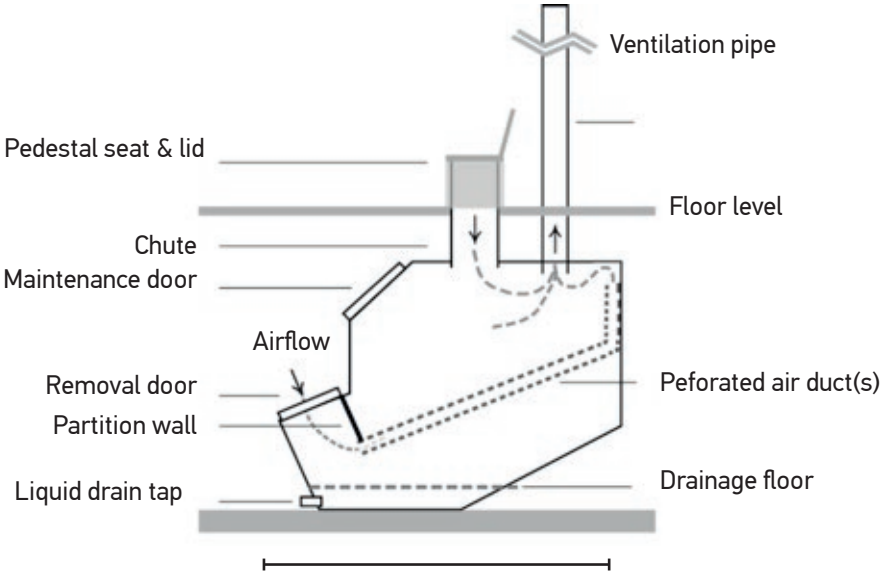


Side & Back Views:
Includes Urine collection system

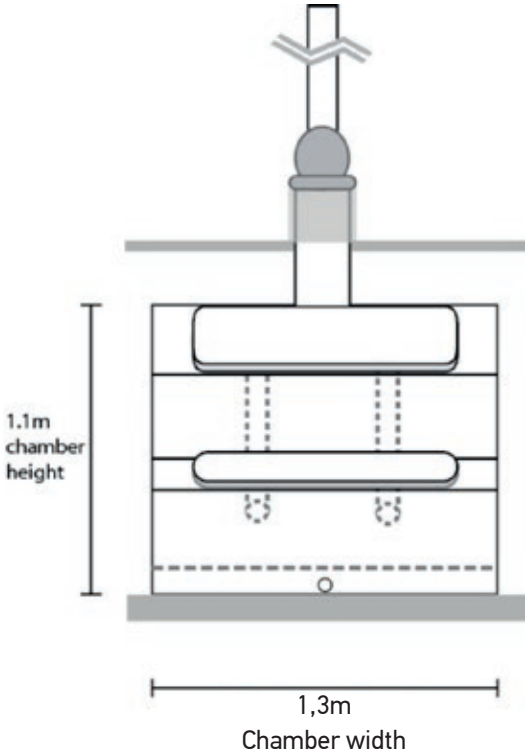
CONTINUOUS PROCESS: CLIVIS MULTRUM

This is a commercial unit, usually fitted inside houses, under the floor.

Side View



Rear View



III

Banana Circles and How to Make Them

THE BANANA CIRCLE IS DERIVED FROM PERMACULTURE PRINCIPLES, AS A WAY TO PROCESS ORGANIC WASTE ONSITE WITH THE MINIMUM OF EFFORT.

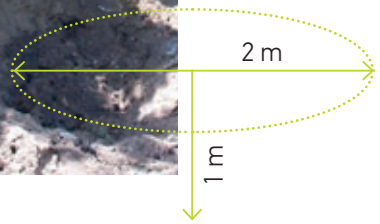
The Banana Circle can be built next to the compost toilet so that any liquid draining from the bottom of the toilet goes into the Banana Circle to feed the bananas. The Banana Circle can also be fed with any other small organic waste materials, as it is centred on a compost heap that feeds the bananas.

The Banana Circle is a simple hemispherical pit lined with flattened cardboard boxes, and filled with any small organic wastes that are available, such as kitchen waste, ground sweepings and garden trimmings. A set of pictures is provided below to show how to build a Banana Circle. The same technique can be used to grow papayas, but bananas and papayas should not be grown together as they compete and one will kill the other soon. Other plants may be grown around such a pit compost system; the technique is not exclusive to bananas. But this is a very useful way to simply process household organic wastes and produce a food crop at the same time. For example, in many atoll locations bananas are hard to grow and make the plants bear fruit, whilst a Banana Circle provides food to the plant which is usually enough to make them bear fruit.

A Banana Circle compost heap can also absorb some old food tin cans (not aluminium) and paper, if added in moderation. In many Pacific Island villages, sweeping up the leaves around the house is part of the daily routine. Where a house has a Banana Circle, the sweepings can be swept straight into it rather than into a heap by the road, or into the garbage for removal. This builds on an ancient composting technique on atolls, of sweeping leaves and other rubbish on the ground into a pit near the house. The Banana Circle is a refinement of these ancient traditional practises. The cardboard is used to encourage a mat of roots to grow along a damp lining to the pit, so that water is retained, and the full nutritional value of the compost is recovered by the plant.

HOW TO MAKE A BANANA CIRCLE:

1 Dig a hole about two metres across and one metre deep, of a round shape like half a ball.



2 Line the hole with flattened cardboard boxes. This serves to hold water and the roots will run along the cardboard over time, making a root mat under the compost pile.

3 Fill the hole up with organic materials such as leaves, kitchen waste, old plants etc to about one metre high. Avoid large sticks, and where palm leaves should be chopped up with a bush knife into several pieces. Throw several buckets of water over it to start it off with a bit of moisture..

4 Plant four banana plants around the edge. Put a bit of compost - or good, rich soil - in each hole before planting the Bananas. You can also plant Papayas around the circle. But do not mix Papaya and Bananas.

5 Put any of your organic waste into the circle, on a daily basis, so that it feeds the bananas. Throw any spare water into the circle too, such as from washing dishes.

6 Enjoy your banana crop!

IV

Frequently Asked Questions

What makes a compost toilet hygienic and sanitary?
Containment, always having the seat closed, and good air circulation.

How are pathogens dealt with in a compost toilet?
Pathogens are anaerobic microbes that die off in the presence of oxygen. They can be killed by heat, but in compost toilets it is also good aeration and long storage times that ensures the die off of pathogens.

What are the risks with compost toilets?
A well designed and maintained toilet will be safe and not smell. Overloading of urine or water and poor air circulation are the main reasons for poor functioning. Hand washing is always important for good hygiene, and all composted human wastes should be handled with care when recycled back to the land.

What is required for effective composting?
A mix of manure and dry carbon organic matter, some moisture - but not too wet - air circulation throughout, and compost microbes.

It a compost toilet easy to use?
It is very simple. All human wastes go in plus the toilet paper, and then a cup or handful of cover material - Bulking Agent - is added. The toilet seat is always left down after use. Sanitary pads and non-organic matter should not be placed in a compost toilet chamber or drum.

What are the maintenance issues?
Any structure will require its appropriate maintenance, but the main issues with compost toilets are the handling and spreading of the composted material back to the land. Guidelines and education about this is important. An appropriate local cover material has to be collected, stored, and made available in a small container beside the toilet.

What are the principle benefits of compost toilets?
Human wastes are recycled in a sanitary way, without exposing people to pathogens or polluting the environment.

What should I do if I find flies are coming out of the toilet?
It sometimes happens that a certain type of fly gets into the toilet and breeds. If you open the lid and lots of black flies come out, get some ash from a fire place and tip it down the toilet, so that the compost pile is well covered. Lime as used in gardens will also do well. Very fine coral sand/dust is also suitable. The ash or the lime will stop the flies, but it will also slow down the composting, so your toilet will take a few days to get back to normal composting.

What do I do if my toilet smells strongly?

This is almost certainly caused by too much urine in the compost pile, but can be also caused by not enough air circulation, or the compost too wet. Check that the seat is kept closed at all times when not in use. Make sure the seat sit right down on the top of the toilet, with only the very smallest of gaps, if any. Make sure that the air vent at the lower end of the toilet chamber is clear. Make sure any outlet vent is clear. If someone is using the toilet for frequent urination, either add a urine catcher or make other arrangements for urination elsewhere.

V

References and Resources

The documents listed below provide a very good resource of information and studies about the use of compost toilets.

An Evaluation of Waterless Human Waste Management Systems at North American Public Remote Sites: Geoffrey Becker Hill University of British Columbia 2013

Basic Overview of Composting Toilets (with or without urine diversion); Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) EcoSanRes Programme, Stockholm Environment Institute 2009

Case Study of Sustainable Sanitation Projects at Ecological Settlement in Allermöhe, Hamburg, Germany; Sustainable Sanitation Alliance, 2009

Clean Communities: a Practical Guide to Building and Maintaining Toilets in the Pacific; Live and Learn, 2011

Compost Toilet Guidelines; Gisbourne District Council, New Zealand, 2010

Guidelines on the Safe Use of Urine and Faeces in Ecological Sanitation Systems; EcoSanRes Programme, Stockholm Environment Institute 2004

Guidelines on the Use of Urine and Faeces in Crop Production; EcoSanRes Programme, Stockholm Environment Institute 2004

Microbial Exposure and Health Assessments in Sanitation Technologies and Systems; EcoSanRes Programme, Stockholm Environment Institute 2011

The Humanure Handbook: A Guide To Composting Human Manure
By Joseph Jenkins 2005 ISBN-13: 978-0-9644258-3-5

Trees as Recyclers of Nutrients Present in Human Excreta: Peter Morgan
Aquamor Ltd. 2011

Urine Separation - Closing the Nutrient Cycle; VERNA Ecology Johanssen 2000

Who Guidelines for the Safe Use Of Wastewater, Excreta and Grey Water; World Health Organisation, four volumes, 2006

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