

ENVIRONMENT DESIGN GUIDE

URINE-SEPARATION AND DRY COMPOSTING TOILET TRIAL – DEMONSTRATION IN A SECONDARY SCHOOL

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The paper and its companion paper summarise reports published by the consulting firm GHD in 2003 and 2009 and, in particular, they summarise final results of a two year trial of six urine-separating dry composting toilets and 2 waterless urinals, at a new secondary school in Victoria. This paper discusses the project in general and the companion paper CAS: 55B: Urine-Separation and Dry Composting Toilet Trial – Agricultural Use of Residues, reports on the successful agricultural trial in which the collected urine was used as fertiliser.

Usage of the facility was lower than anticipated but the majority of students who used the toilets found them satisfactory and sufficient information was obtained to draw useful conclusions. Whilst the installation cost was considerably more than for water-flush toilets, it is concluded that the overall economics of dry sanitation may become favourable if water and fertiliser costs significantly increase. Further demonstration on a large scale would be desirable, although it already appears that health risks with a properly designed and operated dry sanitation system are no greater than with conventional sanitation.

Keywords:

composting, conservation, recycling, school, urine, separation, toilets, water, dry, sanitation, desiccating, energy, health, risk



Figure 1 The urine-separating dry composting toilet block

Note the 'greenhouse' translucent wall above the wash trough, which is used for solar air heating. (Source GHD, 2009)

1.0 PROJECT DETAILS

Client:

Victorian Department of Education and Early Childhood Development

Sponsors/Partners:

The Victorian Smart Water Fund, the Victorian Department of Education and Early Childhood Development, GHD and other parties involved have funded the trial

Project:

Urine separating composting toilet system and building, Maryborough Education Centre, Maryborough, Victoria

Design Consultant:

GHD

Architect:

Oaten Stanistreet Architects

Equipment:

Environment Equipment Pty Ltd

Builder:

JA Dodd Ltd

2.0 INTRODUCTION

There are 2.6 billion people in the world today who lack any adequate sanitation and, in developed countries, water-flushing of excreta to sewer is coming under scrutiny. With increasing population, declining rainfall in many areas, the availability of reducing phosphate fertilisers and the need to reduce fossil fuel use, waterless sanitation systems that also recover nutrients offer a more ecologically sustainable solution than water-flushed toilets.

Waterless systems are probably the only affordable sanitation option for those lacking access to a sewerage system and water supply but they also have significant advantages in locations where there is already sewerage and water supply. The use of urine separation on its own, or urine separation with composting or desiccating toilets could:

- save water
- recover nutrients sufficient to produce the majority of a community's food production requirements
- save energy otherwise used for pumping and treating sewage
- save energy otherwise used in fertiliser production
- secure future supplies of phosphate fertiliser

This demonstration project set out to show that urine-separating composting toilets can be used without nuisance, and that the residues recovered could be beneficially used in agriculture to replace chemical fertiliser.

3.0 WHY USE URINE SEPARATION AND COMPOSTING TOILETS?

3.1 Issues with Human Excreta Management

After a clean water supply, a safe and effective means of human excreta management is the next most important measure to maintain public health (GHD, 2003). Conventional sanitation treats excreta as a waste to be taken away and disposed of, neglecting the resources in excreta. Figure 2 (from GHD, 2003) shows approximate volumes, masses and proportions of key components of domestic sewage being greywater (waste from basins etc) and blackwater (waste from water closets) that are contributed by each resident in an affluent country and shows the approximate proportions coming from the toilet. These figures were derived from a review of published data on excreta loads and typical data for domestic sewage. The data on urine composition obtained at Maryborough suggests that the per-capita contributions from urine in Figure 2 may be overstated but support the conclusion that significant percentages of pollutants in domestic sewage come from excreta and particularly from urine. Using the Maryborough composition data for urine which are listed in Appendix 1, typical domestic sewage data and assuming a person contributes 1.4 litres a day of urine, suggests that around 60 per cent of the Total Nitrogen (TN), 30 per cent of Total Phosphorus (TP) and 40 per cent of Total Dissolved Solids (TDS) in domestic sewage comes from urine. Similarly significant Biochemical Oxygen Demand (BOD, a measure of biodegradable organic matter) and Suspended Solids (SS) come from excreta.

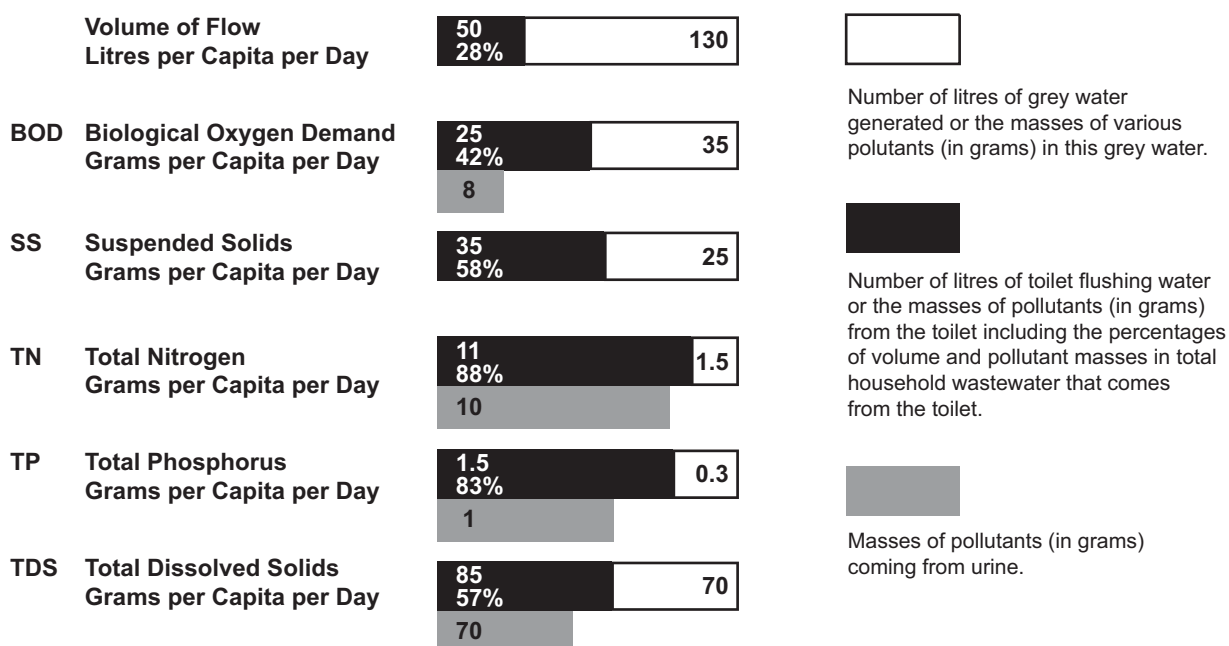


Figure 2 Load components making up typical domestic sewage

(Source GHD, 2003)

Nitrogen and phosphorus are nutrients contained in sewage that are difficult to remove once in the sewerage system and which can cause environmental harm if released to the environment. The challenge is to collect, process and use excreta in such a way that there is no nuisance and no risk to human health.

3.2 Alternative Toilet Systems

Several technologies exist for reducing the use of potable water in toilets such as dual and low flush, ultra-low flush (vacuum), use of recycled greywater for flushing or use of roof water for flushing. Unlike a dry toilet, these do not have the advantage of reducing pollutant, salt and nutrient loads to sewer. In the case of recycling of greywater or low flush volumes, the concentrations of pollutants in sewage are increased which, in the case of salinity, may reduce reuse potential. Other options such as pit latrines, chemical toilets and incinerating toilets have limited applications, do not allow resource recovery and can have significant environmental impact. Waterless urinals connected to sewer do save flushing water but the pollutants still have to be treated and salts will remain. Recovery of nutrients in conventional sewage treatment is limited. The types of dry or low-flush toilet technology that can provide some or all of the benefits discussed above include:

- urine separation with recovery for agricultural use, either with or without low volume flushing
- urine separation combined with either composting or desiccating toilets
- composting or desiccating toilets with on-site urine evaporation

3.3 Advantages of Urine-Separating Dry Composting Toilets

There has been considerable research around the world into both urine separation and the agricultural use of urine and into composting toilets, much of which was summarised in a previous feasibility study by the engineering consultants (GHD, 2003). This study concluded that dry composting toilets with urine separation, with a scaled-down conventional sewerage system for greywater and a road-based transport system for excreta residues, may be no more costly than conventional sewerage. The study also concluded that this form of dry sanitation should not use significantly more energy than conventional sewerage, provided the energy saved in fertiliser manufacture is taken into account, and the energy use for ventilation and heating associated with the composting toilet can be minimised. Advantages identified included:

- **Reduced water use** – about 18 per cent of average household water usage (around 18 kilolitres per capita per year (kL/c.yr) saved out of 96 kL/c.yr used by the average Melbourne household in 2003) and 28 per cent of domestic sewage discharge would be avoided by eliminating toilet flushing.

- **Destruction of pathogens** – because composting can raise the temperature of faecal matter and toilet paper to 60°C or more, pathogenic microorganisms can be destroyed and a compost produced that is safe to use in agriculture (GHD, 2003).
- **Captured nutrients** – over 60 per cent of the nutrient, nitrogen, over 30 per cent of the nutrient phosphorus and over 40 per cent of the total salts and perhaps 25 per cent of the BOD discharged by a household to sewer can be recovered in a transportable and reusable form.
- **Reduced load on infrastructure** – reduced discharge to sewer will extend the life of wastewater collection and treatment systems as well as reducing loads discharged to receiving waters, reducing the salinity of recycled water and reducing the mass of biosolids generated.
- **Low odour** – the necessary ventilation with composting toilets results in no odour release in the toilet room.

4.0 THE MARYBOROUGH DEMONSTRATION PROJECT

4.1 Feasibility Study

Interest from the community involved in the design of a new school in Maryborough spurred the Victorian Department of Education and Early Childhood Development to commission the engineering consultants, GHD, to undertake a feasibility study of providing urine-separating composting toilets in schools (GHD, 2005). A comprehensive risk assessment concluded that only a small number of additional risks were identified for urine-separating composting toilets compared to water-flushed toilets. Fly breeding was a possible risk that needed investigation. The Department agreed to a trial installation at the Maryborough Education Centre and successful application for funding was made to the Smart Water Fund. The Fund is an initiative of the Victorian Government and the Victorian water industry supporting the development of innovative water conservation, water recycling and sustainable biosolids solutions. Other contributions came from the Education Department, GHD, Oaten Stanistreet Architects and Environment Equipment Pty Ltd who were the composting toilet suppliers.

4.2 Equipment Selection and Facility Design

There are many types of composting toilets available commercially. One of the two main types is a system which works on a continuous basis where fresh material is added to the top of a compost pile from one or more toilet pedestals and composted excreta is removed from the base. The other type is a carousel system, where several individual compost bins stand on a turntable within an enclosed composting chamber. It was this second type that was selected for this project. One or

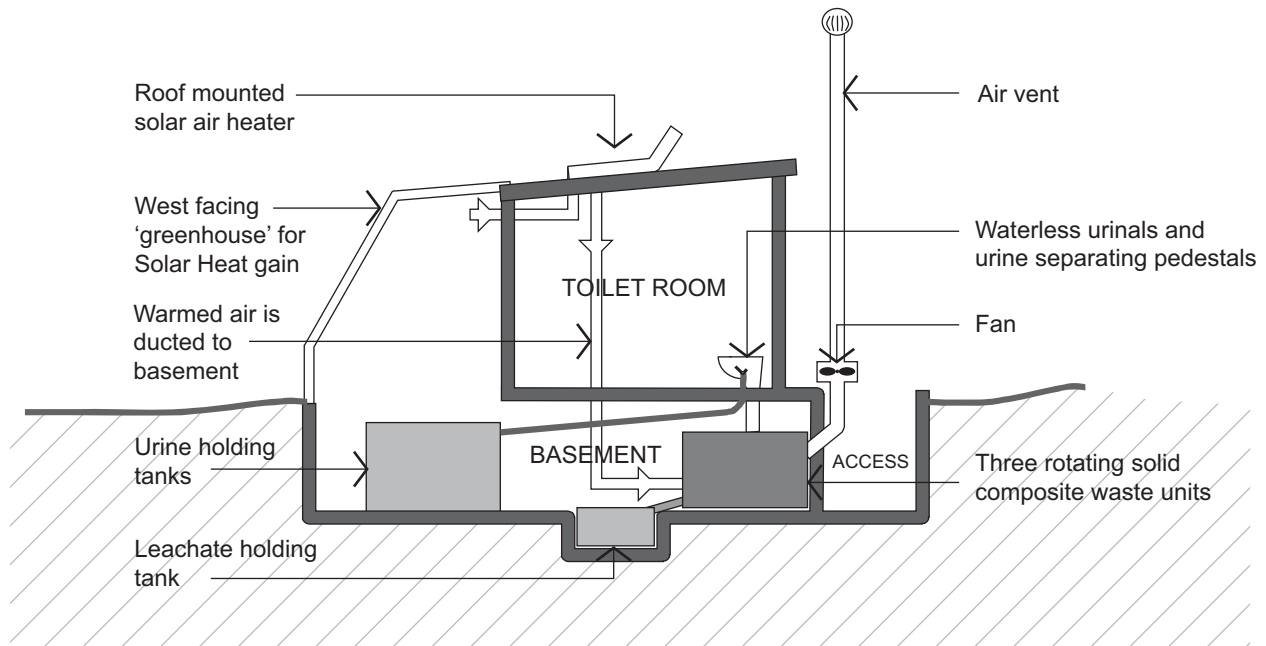


Figure 3 Schematic cross section of the facility showing a composteer and tanks

(Source: GHD, 2009)

two pedestals on each chamber discharge into bins below and, when a bin is full, the turntable is manually rotated to bring an empty bin under the pedestal. The full bin remains on the turntable for several months to compost and thus minimise the risk of pathogens being present in the finished compost. In both types, urine is typically either discharged to a greywater system, or an attempt is made to evaporate it, though the latter often leads to difficulties with excess liquid and odour.

Any type of composter can be connected to urine-separating pedestals. Even with urine-separating pedestals there will be some liquid which is referred to as leachate that drains through the compost. Urine separating pedestals were selected both to capture urine for use in agriculture and to assist composting of the solids as systems that do not separate urine have been noted to suffer from water-logging and an excessive nitrogen to carbon ratio which causes toxicity due to high ammonia.

Figure 3 is a simplified cross section of the building. Three composting units, (which can be seen on the left in Figure 5) were supplied, each serving two urine-separating ceramic pedestals. The pedestal shown in Figure 4 illustrates the large opening for faecal matter and toilet paper and the small collection bowl and outlet for separated urine. Eight, 50 kg capacity High Density Polyethylene (HDPE) compost bins are arranged on a carousel within an HDPE composting container. The female toilet has four pedestals on two composters, and the male toilet has two pedestals on one composter plus two waterless urinals.

Separated urine flows via 100 mm PVC pipes to a 4.3 kL HDPE urine holding tank the edge of which can be seen on the right in Figure 5. Unseparated urine and other 'leachate' drains through the holes in the bottom

of the composting bins on the carousel, collects in the base of the composters and flows via 32 mm PVC pipes to a 2.7 kL leachate tank, which is set into the floor as shown in Figure 5.

The composters and tanks were sized based on the assumption that 200 students would use the toilets over normal school hours and that, whilst at school, they would contribute 30 percent of the published daily urine and faecal matter loads from adults. It was estimated it would take 6 to 12 months to fill the urine and leachate tanks, and around 1 to 2 years to fill all 24 compost bins. Table 1 summarises the design loads.



Figure 4 Urine-separating pedestal

(Source: GHD, 2009)



Figure 5 Basement showing composters, in-floor leachate tank and urine tank

(Source: GHD, 2009)

4.3 Approvals

Current guidelines and regulations in Victoria as well as in other parts of Australia do not address either urine separation or off-site use of residues on agricultural land surfaces so several steps were taken to gain approval for the project. Health risks were extensively researched and presented to both the Victorian Environment

Protection Authority (EPA) and the municipal council, along with details of the proposed agricultural trial. The EPA advised that the composting toilet proposed to be used was on its approved list, that this approval extended to use in schools and that it would have no objection to the trial, provided that:

- the agricultural use of residues complied with published requirements for the application of biosolids
- the Chief Veterinary Officer of Department of Primary Industries had no objections to the agricultural trial
- the municipal council approved the installation of the toilets and agricultural use of the waste on the nominated farm.

Council required that a formal application and fee be submitted as for a septic tank, although there are no similarities with a septic tank and no on-site discharge. Council also had concerns about the agricultural trial. The farmer who agreed to accept the residues for trial application was concerned about the effect on his ability to complete a 'National Vendor Declaration', which is effectively a statutory declaration to confirm sheep being sold have not grazed on contaminated pastures. However, this largely relates to pesticide application rather than the sorts of materials that were likely to be found in the waste from the trial.

Component	Yearly Loads kg/yr			Total
	Compost	Clean Urine	Leachate	
Total Nitrogen	20	60	30	110
Total Phosphorus	10	10	0	20
Potassium	10	10	0	20
BOD	400	80	40	260
Organic Carbon	200	40	20	260
Total Salts	300	400	200	900
Calcium	10	0	0	10
Magnesium	0	1	0	1
Sodium	10	20	10	40
Total Solids	500	400	200	1100
Water	200	7 400	3 500	11 100
Total Mass	700	7 800	3 700	12 200

Table 1 Design excreta Load from 200 Users

	Original Proposed Design (20 fixtures)	Actual (8 fixtures)	Optimised Building Design (20 fixtures)	Conventional Toilet Option (20 fixtures)
Total Capital Cost including design	\$318,000	\$335,000	\$211,000 min.	\$100,000
Capital Cost per Fixture	\$15,900	\$41,900	\$10,600 min.	\$5,000
Additional Capital Cost per Fixture Compared to Conventional	\$11,900	\$36,900	\$5,600 min.	N/A

Table 2 Estimated and actual capital costs for a urine-separating composting toilet facility

Costs for the installation and the capital cost per fixture are shown, disregarding costs which are equivalent for composting and conventional toilets such as the toilet room, handbasins etc.

Approvals from all stakeholders were eventually gained, with a condition from the Chief Veterinary Officer that no pigs or cattle be grazed on the land due to the risk of human parasite transmission. If wider adoption of the technology is to occur, specific regulations and encouragement by governments will be required.

4.4 Construction Costs

Prior to construction, it was estimated (second column of Table 2) that the urine-separating composting toilets would cost \$10,900 more per fixture than conventional water-flushed toilets, but, had the building arrangement had been optimised for dry toilets, this difference could reduce to around \$5,600.

Table 2 shows that the installation, costing \$41,900 per fixture, cost far more than estimated. All equipment, comprising: the composter units, pedestals, urinals, the leachate and urine tanks, the odour-control biofilter, the solar air heater and air ducting, cost \$41,500 out of the \$335,000. Special monitoring equipment, water metering to the hand-wash basins and metering of another toilet block in the school to allow comparison of water use, an electric heater, provision for a gas heater and special signage cost a further \$27,000. Thus equipment and monitoring costs on their own amounted to only \$8,600 per fixture.

4.5 Potential for Capital Cost Reduction

This very high additional cost per fixture was largely high building cost. There were several reasons for this, being: the building was slab-on-ground construction necessitating a basement construction (in rock) with associated access and drainage costs; the greenhouse structure was expensive yet only provided limited benefit, and the price for the construction of the amenities building itself was negotiated with the builder as a variation after the main school construction contract was awarded based on conventional toilets.

It is considered that the extra cost for this project (\$36,900/fixture) should have been no more than \$25,000 per fixture compared with conventional toilets,

though if constructed on an appropriately sloping site and with economies of scale, it may have been possible to reduce this to as little as \$5,000 to \$10,000 more per fixture.

5.0 OUTCOMES FROM THE STUDY

5.1 Operating History

The secondary section of the new school was opened and the installation was commissioned in April 2007 with monitoring continuing until May 2009. A seven week closure of both male and female toilets occurred in November 2007, when flooding caused the leachate tank to float in the basement floor, necessitating repairs. Other short closures occurred in response to incidences of students smoking in the toilets and dropping cigarette butts and lighted paper down the toilet pedestals.

5.2 Quantities of Residues Collected and Estimated Usage

Usage of the toilets was much lower than the expected 200 visits per day. Over the two years of operation the toilets were open for 313 days, with the estimated usage shown in Table 3. Attempts to count the number of people using the toilets failed, so estimates were made based on assumed contributions per use. Whilst these estimates are not reliable, they do provide some data to guide design.

5.3 Ventilation and Odour Control

The ventilation system, shown schematically in Figure 3, provided warmed air to the base of the composters with the objective of warming the composting space and creating a downdraft at the pedestals to prevent odour release into the toilet room. Each composter had a 22 W mains-powered fan (that is, 11 W per pedestal) which exhausted air to a vent above the roof line. These three fans were controlled by time clocks for much

	Estimated	Actual	Comments
Students uses per day	200	7 urination	Assumed 0.15 L per event
		<1 defecation	Assumed 50 g of dry solids (including toilet paper)
Total urine	7 800 L/yr	280 L in 313 days	
Total leachate	3 700 L/yr	1000 L in 313 days	
Total compost	700 kg/yr	15 kg in 313 days	(28% moisture)

Table 3 Usage data

of the trial to limit energy consumption, and also to prevent drawing cold night air into the composters. Users did not report any odour although odour was noted by the cleaner when timers controlling the ventilation fans failed. The urine and leachate tanks were sealed to prevent odour release. The air vents from both tanks discharged into the base of an in-ground odour control biofilter.

Air velocity into the outlet of a single open pedestal was measured to be around 0.24 m/s (range 0.18 to 0.3 m/s), which equates to 23 m³/hr down the 185 mm diameter pedestal outlet. It is considered that a lower velocity down each pedestal outlet of around 0.1 m/s (10 m³/hr) would probably be sufficient to prevent odour release during use and this would reduce the necessary fan power. The total air flow through one composter created by its 22 W fan was around 100 to 140 m³/hr. A lesser flow would be adequate to provide oxygen for composting and would reduce necessary fan power.

5.4 Flies and Spiders

Regular checks noted flies (thought to be *Drosophila melanogaster* which is a small fruit fly commonly found in compost) emerging from the composters on only one occasion. This was contrary to expectations and given the lack of insect screens on vents, is probably explained by the desiccated nature of the compost in this installation. Should greater usage bring flies, generously sized fine screens on vents can be added, users educated to keep toilet lids closed, and insecticides used. The absence of flies also led to an absence of spiders and cobwebs in the air ducts, which in installations at other locations have been noticed and required frequent removal to maintain air flow.

5.5 Water Use

Water usage for hand washing in the installation was an estimated 1.5 to 2.5 L per visit compared to total water usage in a conventional toilet block at the school estimated to be 4.2 L per visit. The conventional toilet block use had lower usage than an expected 6 to 8 L per visit suggesting that not all users flushed the toilets or washed their hands.

Three to nine litres of water was used per day in the installation to keep compost moist (see section 5.9)

which meant that overall water use in the composting toilets was higher than expected. However, as the low usage was probably the primary cause of the need for additional water, this use is not particularly relevant to water usage estimates.

5.6 Energy Use

Energy use was studied in GHD's 2003 report to the Smart Water Fund where it was concluded that establishing a community using urine-separating dry composting toilets with use of the residues for fertiliser replacement, but still having a greywater sewerage system, would use no more energy than conventional sewerage and use of chemical fertiliser. Table 3 compares estimated energy use per capita of conventional sewerage with a composting toilet/greywater sewerage option for an urban area, using energy estimates from this current project. Comparison shows a potential saving in overall community energy use may be possible by introducing this type of dry sanitation.

5.7 Composting Temperature

The temperature recorded within the solids collected in one of the composting bins followed the ambient temperature closely, although the effect of the hot air from the solar air heater and greenhouse was to achieve relatively warm temperatures for short periods.

If composting had been achieved, then elevated temperatures of up to 60°C would be expected. Artificial heating of air supplied to one of the two composters serving the female toilets was trialled to see if it would result in composting but there too, despite the composter being warmed to 20°C, desiccation rather than composting was the dominant process and the temperature of compost was no higher than shown in Figure 6.

It is concluded that composting with temperature elevation cannot be readily achieved with the low usage and dryness resulting from urine separation, where these two together caused desiccation of the solid material collected. This is an important conclusion as it indicates that achieving composting at high temperatures cannot be relied upon as a means of inactivating pathogens.

Energy-Using Operation	Conventional Sewerage	Urine-Separating Composting Toilets
Household Toilet Ventilation MJ/c.yr	0	0–303
Transport MJ/c.yr	105	202
Treatment and Reuse of Residues MJ/c.yr	142–434	39
Embodied energy in fertiliser saved MJ/c.yr (negative=saving)	Negligible	70
TOTAL MJ/c.yr	248–540	171–474
Equivalent Diesel Fuel Use (L/c.yr)*	6–14	4–13
Approximate GHG Emissions CO ₂ -e kg/c.yr	19–42	13–34
Lifetime Emissions (50 years) tonnes CO ₂ -e kg/c.yr	1.0–2.1	0.7–1.7

Table 3 Estimates of energy and greenhouse parameters for sanitation options

5.8 Heat and Water Balance over a Composter

There is little published data on the heat and water balances over operating composting systems but it is often reported that it is difficult to achieve elevated temperature aerobic composting in cold conditions. For these reasons, airflow, temperature and humidity logging were carried out extensively during the trial. Maintaining a heat balance over a composter is complex and varies diurnally with ambient conditions. Insulation of the composter, air temperature, humidity, and flow rate, the moisture level in the compost, whether airflow is stopped at night, and artificial heating of a composter are important factors.

Calculations and measurements made during this work (GHD, 2009) suggest that it is likely that heat loss due to evaporation from the ventilation of the compost, plus heat loss due to convection and radiation from an uninsulated composter will exceed heat generation within composting solid waste. Heat losses by evaporation were often up to 400 W per composter and heat losses due to radiation and convection combined were estimated to be 600 W or more. These total losses of 1 000 W compare to a maximum likely heat generation from composting of around 300 W, based on the known heat generation during composting assuming most bins in a composter are reasonably full. With this net loss of heat there is clearly a high potential for failure to establish thermophilic composting. Insulation could greatly reduce convection and radiation losses, and limiting air flow over the compost may reduce evaporative heat loss. However, in a lightly used facility, potential heat losses will certainly exceed any generation from composting. Temperature elevation could only be expected deep within a compost bed where surrounding compost provides insulation and protection from excessive evaporation.

The highest heat input (measured over about 15 minutes) achieved to the composters from the greenhouse and solar air heater system was measured to be around 330 W, although this was not on a very hot day when short-term heat input may be several times this amount. This input was shared amongst the three composters. However, the hotter the inflow air, the greater the evaporative cooling effect and there is no heat input from this source at night.

Intermittent switching on of 500 W of heating on the inlet air to the insulated composter proved sufficient to maintain the compost mass and air temperature close to 20°C throughout the year, though this might be reduced to 100 W to 250 W if the composter is insulated. It is concluded that, if composting with temperature elevation is required in an on-site composting system, then most or all of the following features are probably necessary:

- a large mass of compost to provide heat and insulation and limit evaporative cooling, that is, high usage
- insulation of the composting vessel
- limiting the air flow over the compost to the minimum necessary to provide oxygen so that evaporative cooling is limited
- means of supplying some heat to the compost to aid the process in cold weather.

The peak short-term rate of water loss from within a composter was measured to be up to 6.6 L per day, with only limited compost in two of eight bins and little if any liquid in the base of the composter. With more compost, higher evaporation and hence evaporative cooling is likely. The measured daily loss of 2 to 3 L per day of water from within a composter during summer and winter could be higher with more and wetter compost.

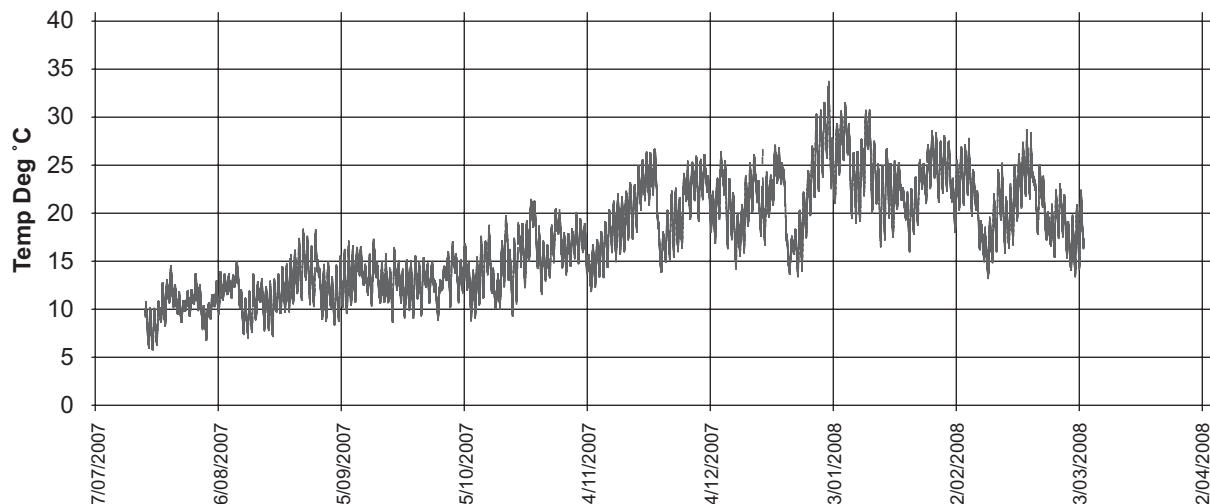


Figure 6 Temperature of compost within compost bins

5.9 Desiccation versus Composting of Solids

The solid waste was always noted to be dry and it is likely that moisture content rarely exceeded 30 per cent by weight. As mentioned above, the desiccation which is assisted by urine-separation, appears to eliminate fly breeding and also reduces the potential for odour so it has some distinct advantages over on-site composting.

One major disadvantage of desiccation is potential fire risk if lighted material is dropped into the pedestal. In the trial, mostly the lighted material that was dropped into the composters by students did not cause any damage but on one occasion, the contents of a compost bin smouldered and generated significant smoke.

This risk was exacerbated by the low use, leading to desiccation of the compost bin contents. Following identification of this risk, 0.5 to 1.5 L of water was added daily by the cleaner to each of the six operating compost bins and this prevented further incidents.

Another disadvantage of desiccation is that solids do not compost correctly and thus the lack of heat derived from thermophilic composting, may result in higher concentrations of some pathogens in the waste than in effectively-composted material. Partial or full desiccation of solids in a dry toilet does not preclude off-site composting or other off-site processing. As ambient air in a dry climate will provide adequate desiccation for much of the year, facilities such as the 'greenhouse' system used in this project may not be necessary. The greenhouse systems were developed partly as a means of evaporating urine in non-urine-separating composting toilets, though the more compact solar air heater used at Maryborough would be useful to warm the air, and assist in desiccation and it is simple to roof mount.

5.10 Cleaning

The cleaner, who also undertook some of the monitoring, kept the toilet pedestals and rooms very clean without adding water to the pedestals. A 1:5

vinegar to water solution was used to wipe over seats and pedestal surfaces and the cleaner found this to be effective. The waterless urinals and other surfaces in the toilets were cleaned in a similar way. It was not necessary to clean the 250 mm diameter HDPE drop pipes below the pedestals and these appeared to remain clean. Cleaning of the dry toilets took no more time than cleaning of conventional toilets.

5.11 Health

The cleanliness of the pedestals, absence of flies and isolation of the compost, urine and leachate in the composters and tanks in the basement meant that there was no means of transfer of any pathogenic microorganism from excreta to users. Both the investigation team and cleaner used gloves and sometimes dust masks as well as frequent hand washing, and soap, hot water and paper towels were supplied in the basement for operating and investigating personnel. No instances of illness were noted either in students, investigators or the cleaner. The analyses carried out on urine and leachate reported in Appendix 1 indicate considerable numbers of faecal bacteria were present but these numbers were not so high as to indicate a significant risk of disease transmission from these materials. Likewise, the desiccated compost had relatively low concentrations of indicator bacteria.

5.12 Other Physical Design Issues

It would have been desirable to provide full head height in the basement.

The architects were requested to design the lighting such that it did not shine down the pedestals to illuminate the solid waste, and this was achieved successfully.

Ceramic rather than the standard fibreglass pedestals were used to provide an aesthetic of high quality and for ease of cleaning.

5.13 Student Behaviour

The toilet block is hidden from view from most walkways and staffed office areas around the school. There were a number of instances of problem behaviour with the frequent dropping of various items and litter down the pedestals. The only damage caused to the toilet equipment has been one broken seat and the smouldering within one of the compost bins caused by dropping lit paper. The frequent dropping of cigarette butts into the toilets caused only localised charring of compost.

5.14 User Attitude and Acceptance

An initial user survey was carried out in March 2007 prior to the new school opening. There were 68 responses received which indicated that:

- The majority of students (82 per cent) did not know that the Science/Arts building at the new school had dry composting toilets installed before seeing the questionnaire or visiting the school on the day. However, 87 per cent of staff did know about the toilets.
- The majority of students (82 per cent) had never used a composting toilet before.
- 28 per cent of female students and 46 per cent of male students said they would not avoid using the dry toilets

A second user survey was carried out post commissioning in May and June 2008 with 177 responses, and found that:

- Of the respondents, only 25 per cent had used the composting toilets – 17 per cent of females and 35 per cent of males, which was a partial explanation of the low usage.
- Of the respondents that had used the toilets, 46 per cent felt that the experience was not as bad as expected, with only 18 per cent not liking the experience.
- Environmental and water saving aspects were found to be what users liked most about the facility. Users indicated that the smell and the unconventional nature of the toilets were what they disliked most, although observations of smell were almost all related to cigarette smoke.
- Most users (74 per cent) were either pleasantly surprised or considered the toilets were not as bad as they expected after using the facility. Of female respondents, 35 per cent who used the toilets were pleasantly surprised, whereas a lesser percentage of male respondents (23 per cent) were pleasantly surprised. Only 10 per cent of female respondents reported they did not like the experience, whereas 23 per cent of male respondents reported they did not like the experience.

- The smell of smoke or the use of the facility by smokers was found to be a consistent deterrent to use of the toilets. Other comments received indicated that they did not use the facility for practical reasons such as location.

In summary, the surveys indicated that only 25 per cent of students who responded to the second survey had used the toilets and the reasons given for not using the toilets included reluctance to use dry toilets (particularly amongst females); use of the toilets by smokers; and location. Of the students who did use the toilets, the majority found them either not as bad as expected or they were pleasantly surprised by the experience.

6.0 CONCLUSIONS

The project was only partly successful as a built amenity in that usage was not sufficient to fully assess performance. However, much was learnt from the project both technically and in relation to user behaviour and attitude. Specific lessons learnt in the project were:

Aesthetics and odour – Urine-separating composting toilets can easily be kept clean without water flushing. Properly controlled ventilation prevents any odour within the toilet room. Avoiding lighting directly over the pedestals made it very difficult to see any faecal matter or toilet paper in the bins below. A biofilter on vents from urine/leachate holding tanks is recommended to control all odour from this source. Composter vents rarely resulted in ground level odour but connection to a biofilter may be desirable in sensitive locations.

Urine separation leads to desiccation and a requirement for moisture addition – It is probable that use of rotary-type batch composters coupled with urine separation will mean that desiccation rather than composting is the main mode of operation. Further investigation of the survival of pathogens in desiccated solids is needed. Automated wetting may be necessary to achieve composting if urine separation is also used.

Suggestions for further development – it is the authors' opinion that urine separation with on-site desiccation and off-site processing of solids is probably a better approach where fire risk can be managed and

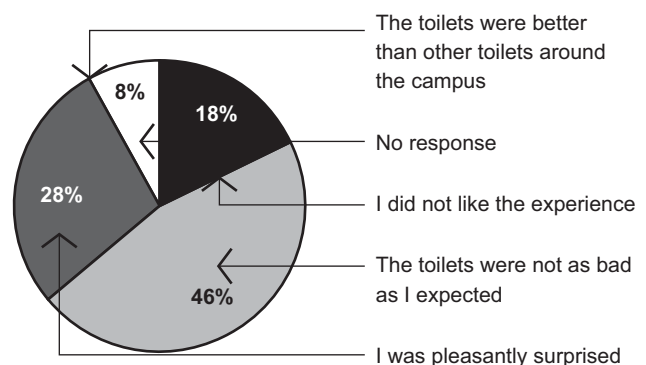


Figure 7 Reactions to a question in the second user survey

that urine separation with solids being discharged to sewer is appropriate as an interim stage, for retrofitting or where the risk of fire is not manageable. As concluded in GHD 2003, non-urine separating composting toilets suffer from problems of odour, poor composting performance due to wetness and excess nitrogen, highly contaminated leachate and loss of nitrogen.

Fire protection – a smoke detector and water spray system could be installed within each composter to guard against fire and should be considered in public installations where desiccation of solids is likely.

Achieving elevated temperatures and pathogen destruction during composting – An important conclusion from this study is that it is uncommon for temperatures within current composting toilet systems to be high enough to inactivate pathogenic microorganism. Heat losses from compost by evaporative cooling, radiation and convection are likely to exceed the ability of natural composting processes to generate heat if there is little compost. It is unwise to rely only on achieving disinfecting temperatures.

Vandalism and litter – Waterless urinals had loose-fitting ceramic disks over the outlets and these were occasionally removed and dropped into the composters. The toilet seats were flimsy and lids were at times removed. Placing of litter items and other foreign materials down pedestals was common and presents a major challenge in any public installation as it may prevent reuse of compost. High quality heavy-duty door locks and hinges are needed to resist vandalism and unauthorised access to the equipment

Reducing cost – Elimination of the greenhouse structure, building on a slope or on piers to provide low-cost sub-floor space, use of standard plastic tanks for urine and leachate, and simplification of composting equipment should reduce the capital cost to an affordable level. A desiccating toilet with remote composting would further reduce cost.

Gaining Acceptance of Users – Clearly the low use by students was a major impediment in this demonstration project. Overcoming this in a secondary school would require commitment from the teaching and administration staff and providing only waterless toilet blocks so that there is no choice. The majority of the secondary students in this case did appreciate the value of the project but it only took a minority to disrupt it. It is suggested that any future demonstrations would better be located in a private residential setting where occupiers agree or in a commercial or industrial setting. Use of composting toilets in a tertiary education campus has been successful at the Charles Sturt University campus near Albury (GHD, 2003).

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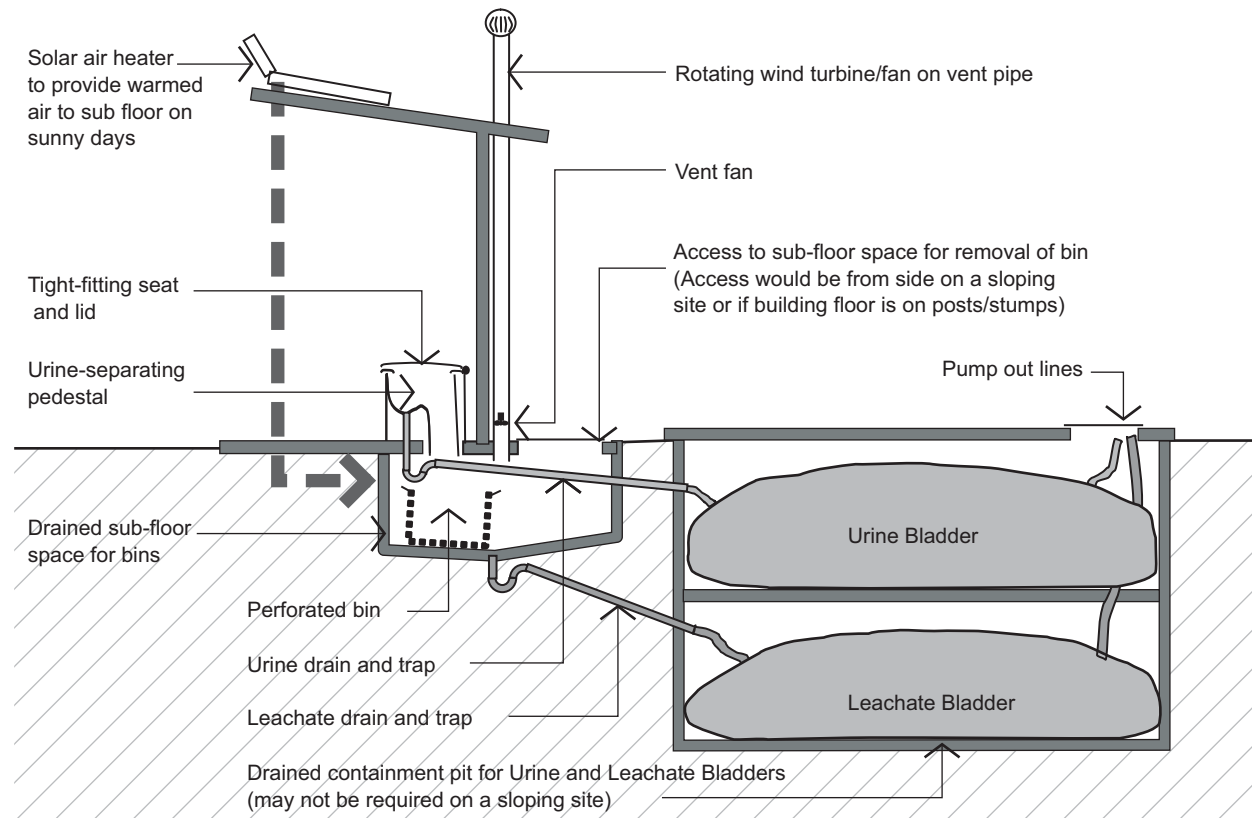


Figure 8 Concept for a urine-separating desiccating dry toilet installation

(Source GHD, 2009)

APPENDIX 1 – AN ALTERNATIVE DESIGN BASED ON URINE-SEPARATION AND DESICCATION

Figure 8 shows a conceptual cross section of a urine-separating desiccating toilet system that should work as well as the composting system used in the trial, and would be substantially less costly to install. The solids would discharge into a perforated bin located in a relatively shallow space below the floor. The floor of this space would drain to a leachate collection bladder (or tank) and the space would be sealed and ventilated via a 5 to 10 W solar/battery or mains-operated fan (per pedestal) to a roof vent equipped with a wind-turbine driven fan/cowl above the roof. When full, the solids bin would be removed and replaced with an empty bin (every few days, weeks or months depending on usage). The solids would be either taken to a composting building serving a number of such toilets, or it could be disposed of as solid waste or by on-site burial.

Collected urine would also drain to a bladder or tank. The use of bladders for urine and leachate may avoid the need for a biofilter on the vents from tanks since little air is displaced as bladders fill. The bladder(s) would be emptied by a vacuum eductor truck (as used for emptying septic tanks) every 6 months to a year and the contents stored for at least 6 months at an agricultural reuse site to allow for pathogen die-off before application to land. The arrangement could be

adapted to high rise buildings in which drop chutes would convey solids direct from pedestals to a ground floor or basement desiccation chamber to which kitchen vegetable waste could also be discharged. The desiccated solids would be composted at a central, properly-managed facility. Co-composting with green waste would probably be beneficial.

This approach has the advantage of producing easy to handle urine and leachate for agriculture with the significant nutrient recovery that allows, plus good quality compost, all with minimum on-site building and equipment cost, minimum energy use and a high level of health protection.

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