

Report on Trial on Urine-Separating Dry Toilets at Maryborough, Victoria

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Summary

A trial of urine-separating dry composting toilets at the Maryborough Education Centre in central Victoria is attempting to demonstrate the benefits of moving towards more sustainable sanitation methods.

The waterless toilet block, housing six Rotaloo® urine-separating composting toilets and two waterless urinals, was opened in April 2007 and has operated for over 250 school days. It is one of 5 student toilet blocks at the school. Increasing acceptance by students, absence of odour in the toilet rooms, absence of fly nuisance, saving of at least 5 kL of water and successful demonstration of the fertiliser potential of separated urine have been the significant achievements so far. There is still prejudice against “different” toilets and composting toilets in particular suffer from some stigma as they are often equated to pit latrines or composting toilets in remote locations which are rarely, if ever, cleaned.

The project was a result of local community pressure coupled with encouraging results of a study of the feasibility of use of dry toilets in schools for the Victorian Department of Education and Early Childhood Development.

The project is being funded in part by a \$170,000 grant from the Smart Water Fund, an initiative of the Victorian government and the Victorian water industry that supports the development of innovative water conservation, water recycling and sustainable bio-solids solutions. GHD and other participants have also contributed substantially to the project.

The final report on the project will be available in mid 2009.

Facility Description

Figure 1 shows the toilet block and its greenhouse-type west-facing structure. The three pipes pointing up from the ground on the right are from an in-ground biofilter, which removes odour from the urine and leachate tank vents. The three pipes exiting the roof are the vents from the composters. Figure 2 shows the basement below the toilet rooms with three Rotaloo® Maxi 2000 composters on the left, the grey PVC 2 700 L leachate tank to collect liquid drained from the composters in the centre (in the floor) and the edge of the black HDPE 4 300 L separated urine tank on the far right.



Figure 1: General View



Figure 2: Basement

Figure 3 shows one of the urine-separating pedestals. There are two pedestals connected to each of the three composters with 4 pedestals in the female toilets and two pedestals in the male toilets. Within each of the three composters are 8 triangular compost bins sitting on a carousel. Two bins are active at any one time. There are two waterless urinals in the male toilets and these drain directly to the urine tank. Urine pipework from the pedestals comprises 25 mm flexible PVC hose connected to 100 mm graded PVC pipework visible in Figure 2. There are inspection openings at each bend in the rigid PVC pipework.



Figure 3: Urine-Separating Dry Toilet Pedestal

The separate collection of urine keeps the compost drier and also reduces the nitrogen-to-carbon ratio to a more optimum value for composting. The drier compost is more permeable to air and this should help the composting process.

Ventilation is an important part of the process. 17 W electric fans on each composter discharge vent maintain a flow of air down through the toilet pedestals and also draw air in from greenhouse. The air flow down through the toilet pedestals prevents odour in the toilet room. Timers control the fans so that energy use and the cooling effect of air is minimised over night.

Expected Benefits of Urine-Separation and Composting Toilets

A report for the Smart Water Fund (GHD, 2003) reviewed much of the work on urine separation and composting around the world and concluded that advantages of a dry sanitation system include:

- up to 19% of an average household water usage and up to 28% of domestic sewage discharge can be avoided,
- over 80% of the nitrogen, phosphorus and potassium, around 55% of the total salts and 25% of the BOD discharged by a household to sewer can be recovered in a transportable, stabilised and reusable form with low pathogen content,
- urine separation on its own can recover a high proportion of these components,
- health risks to householders and sanitation workers are no higher than with conventional sewerage,
- the cost of dry sanitation should be comparable with conventional sanitation,
- energy use for a dry sanitation system coupled with conventional sewerage for grey water would probably be no higher than for a conventional sewerage system taking into account energy savings in fertiliser manufacture.

To illustrate the third point, Figure 4 shows the proportions of key components of domestic sewage that are contributed by each resident from the toilet (black bars) compared to their contributions via grey water discharges (grey bars). In the case of nitrogen, phosphorus and salts, the majority of the contribution comes from urine.

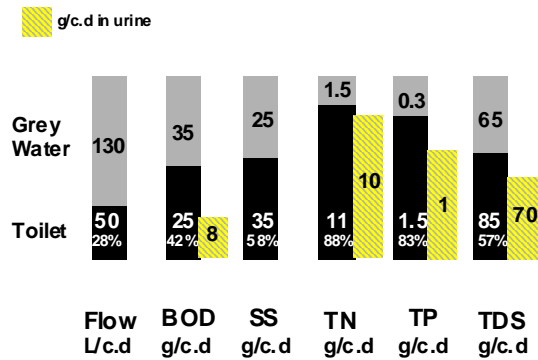


Figure 4: Load Components from Sewage & Grey Water.

Other technologies for reducing water use such as dual and low flush toilets, ultra-low water flush (vacuum) toilets, use of recycled grey water for toilet flushing or use of roof water for toilet flushing do not have the advantage of reducing pollutant, salt and nutrient loads to sewer. Recycling of grey water or low flush volumes increase the concentrations of pollutants in wastewater which may impact on reuse potential.

Results to Date

Data Collected on the Toilet Installation

Overall, the project has demonstrated that such toilets are workable in a school, are odour-free for users, are readily kept in a clean state and that there are no obvious increased health risks compared to conventional water-flush toilets. However there have been several instances of smouldering and one minor fire within the compost bins caused by students dropping lighted material down the pedestals.

Usage has been much lower than the expected 200 uses by students and staff per day. Actual use has averaged fewer than 3 student uses per day, with negligible use by staff. The reasons for this include the location of the toilets at the far end of the school and bad behaviour by some students around and in the toilets that has discouraged use by others.

A significant quantity of data on airflow, air humidity and air and residue temperature has been collected. The literature to date has not included such information. Airflow and evaporation appear to be the main cause of heat loss from the composters.

Airflow into the open pedestals has been measured on several occasions and was estimated to be typically around 0.24 m/s (range 0.18 to 0.3 m/s), which equates to airflow of 23 m³/hr down the 185 mm diameter pan outlet. This has proved adequate (and possibly more than adequate) to positively prevent odour release into the toilet rooms.

Figure 5 shows the temperature history of the urine and compost. The compost has shown no sign of generating heat to date and its temperature has closely followed the temperature of the air.

Fly breeding (of the common vinegar fly often found in compost) has only been noted on one occasion, possibly due to the low use and desiccating conditions.

It has been particularly pleasing to observe that the toilet pedestals have remained clean and (with the exception of one damaged seat) undamaged throughout the trial despite considerable damage to the building itself. The cleaner reports that it is easy to keep the toilets clean and he is certain that there has only been odour within the toilet rooms when fans have been off.

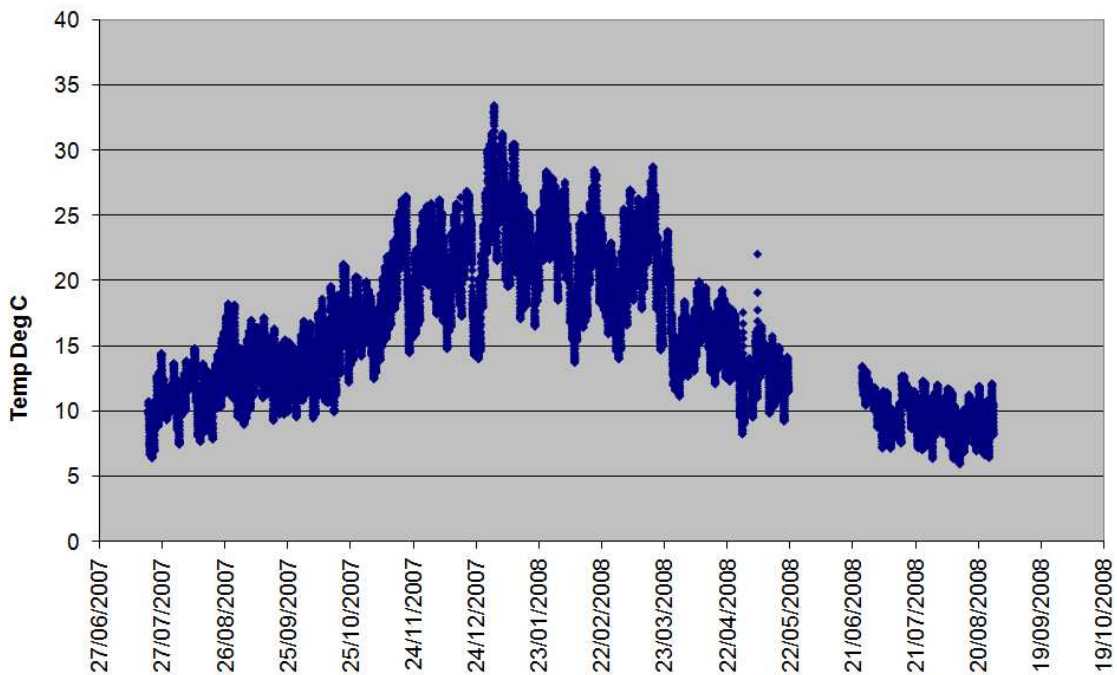


Figure 5: Temperature of “Compost” in one of the Bins

Figure 6 shows the air temperatures at the discharges of composters. High temperature is achieved in hot sunny weather when inlet air from the greenhouse can reach temperatures of over 50°C. A heater was placed on one of the composters (F2) in June 2007 and after overcoming control system problems it has been maintaining temperature at the discharge of this composter at around 20°C. Note that in winter there is little benefit from the greenhouse, partly as there is no provision for storing heat energy accumulated during the day and using it to keep the air stream warm at night. For much of the trial, the ventilation fans have been turned off at night to conserve energy and heat but this was stopped in May 2008 which may explain slightly lower temperatures in August 2008 compared to August 2007.

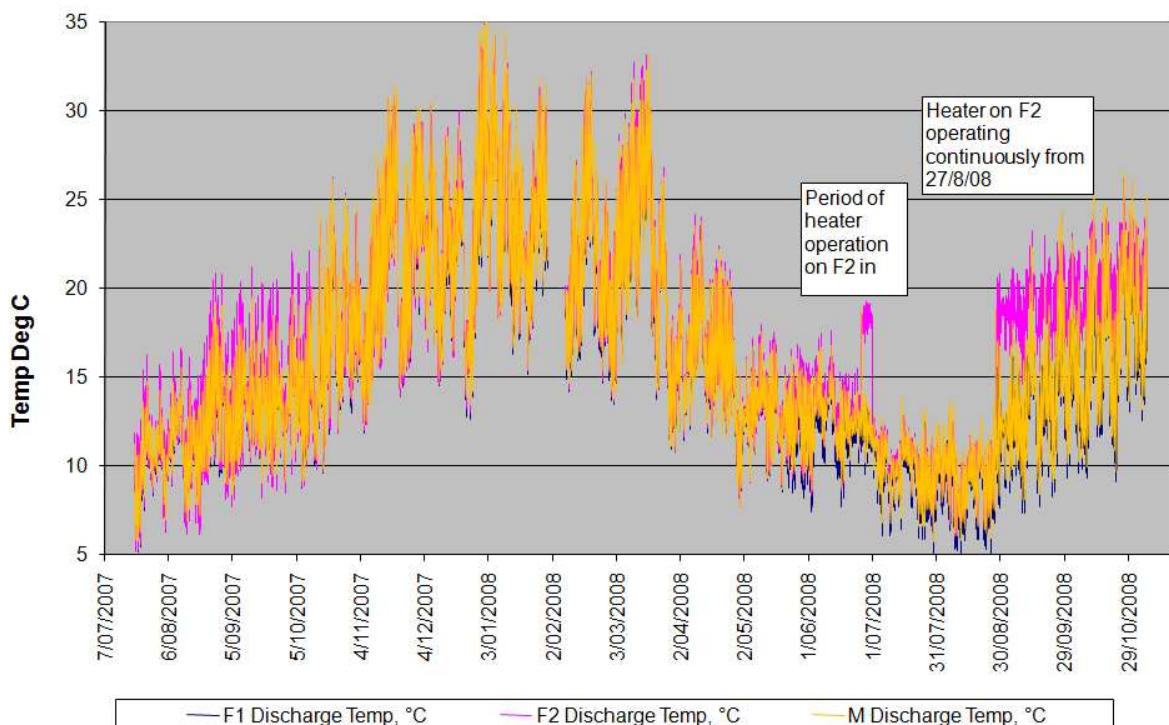


Figure 7: Air Temperatures at Composter Discharge

Urine tank temperature has also been monitored and it has ranged from a minimum of 10°C to a maximum of 27°C. This indicates some possible benefit from the greenhouse although, to keep the urine at the highest possible temperature which is thought to aid pathogen die-off, it would probably be desirable to provide both insulation and a means of getting additional heat into the tank from the greenhouse.

Psychrometric calculations on the air stream indicate that heat loss from each of the composters is probably of the order of 250 W and does not exceed 500 W. In fact, the heater installed on F2 has a 500 W element and it has been able to maintain temperature in F2. Water evaporated is estimated from the same calculations to be possibly up to 2 L/d. Water addition has been up to 3 L/d per composter to control moisture but despite this, compost has still remained in a desiccated state.

It is concluded that the current air system and greenhouse does little to keep the compost material warm in cold periods but it does generate effective desiccation. This desiccation is probably preventing any significant composting.

Cost

The cost of the toilets was expected to be high as the building slab-on ground construction with significant rock. This made for high structural costs. The greenhouse structure was also costly. As well as this a number of items were included specifically for the trial. Thus the additional cost was \$24 000 per fixture, much more than estimated for a large permanent scheme (GHD 2003).

Urine and Leachate Quality and Salt Impact

Table 1 shows the quality of leachate and separated urine collected in the trial based on two rounds of sampling. The first round were estimated from measurements (to allow for some initial water in the tanks). When compared to published concentrations in urine (GHD 2003), these concentrations for urine are of a similar magnitude.

The collected urine is dark brown in colour and contains relatively soft sheet-like pieces of what appears to be chemical scale from the tank surfaces. It has a strong, sharp and unpleasant ammonia-amine odour. Leachate is more dilute as a result of regular addition of water to the compost bins to maintain moisture content and minimise the risk of fire.

Table 1: Available Analyses of Urine and Leachate

Analyte	Units	Estimated Leachate Composition 27/8/08	Estimated Urine Composition 27/8/08	Leachate sampled 6/11/08	Urine Sampled 6/11/08
pH		6.5	7.8	4.5	7.7
Specific Gravity		1.0006	1.0171	1.0064	1.0134
Calcium	mg/L	74	45	82	26
Magnesium	mg/L	161	3.6	170	1.9
Sodium	mg/L	1406	3221	1400	2300
Potassium	mg/L	864	2653	900	2000
Bicarbonate Alkalinity as CaCO ₃	mg/L	121	4926	<10	3000
Carbonate Alkalinity as CaCO ₃	mg/L	0	0	0	0
Chloride	mg/L	2813	5874	2900	4000
Sulfate	mg/L	693	1800	750	1200
Total Solids (Evaporation at 105°C)	mg/L	8237	28421	7300	15000
Suspended Solids	mg/L	683	493	180	1500
Fixed Total Solids	mg/L	6830	14211	6000	9600
Total Dissolved Solids (105°C)	mg/L	6830	28421	7000	14000
Organic Total Solids	mg/L	1406	14211	1300	5200
Conductivity at 25°C	uS/cm	11049	49263	11000	31000
Kjeldahl Nitrogen	mg/L	151	3221	110	2300
Ammonia as N	mg/L	121	436	76	1800

Analyte	Units	Estimated Leachate Composition 27/8/08	Estimated Urine Composition 27/8/08	Leachate sampled 6/11/08	Urine Sampled 6/11/08
Organic N	mg/L	31	2842	30	530
Nitrite as N	mg/L	16	17	14	750
Nitrate as N	mg/L	77	2274	100	1200
Total Oxidised N	mg/L	93	2274	110	2000
Total Phosphorus as P	mg/L	14	360	14	250
Ortho Phosphate as P	mg/L	11	322	12	200
Total Arsenic	mg/L	0.035	0.027	0.019	0.012
Total Boron	mg/L	0.76	0.91	0.80	0.67
Total Cadmium	mg/L	0.0005	<0.0002	0.0020	0.0003
Total Cobalt	mg/L	0.045	0.013	0.051	0.011
Total Chromium	mg/L	0.026	0.015	0.006	0.011
Total Copper	mg/L	1.667	0.603	1.26	0.793
Total Iron	mg/L	19	9	4.2	9.2
Total Manganese	mg/L	0.633	0.066	1.64	0.104
Total Molybdenum	mg/L	0.012	0.028	0.003	0.031
Mercury by cold vapour	mg/L	0.0004	0.0002	0.0006	0.0002
Total Nickel	mg/L	0.130	0.032	0.199	0.027
Total Lead	mg/L	0.036	0.021	0.019	0.036
Total Selenium	mg/L	<0.010	<0.019	<0.010	0.017
Total Tin	mg/L	0.011	0.008	0.003	0.006
Total Zinc	mg/L	0.457	0.309	2.49	0.508
E. coli	per 100 mL	131	<19	<10	<10
Faecal Streptococci	per 100 mL	30	230000	<10	<10
Total Viable Aerobic Count	per mL	100446	1080000	1800	5000

None of the metal concentrations exceeded guidelines for irrigation water.

The Agricultural Trial

The urine and leachate was sucked out of the tanks by a conventional eductor truck and carted 20 km to the agricultural trial site. Approval was obtained from various parties on the basis that the materials applied would meet quality requirements in guidelines published for biosolids application and provided access to the site was limited. Any large scale application will require development of specific guidelines and rules.

The 585 L of urine and leachate collected was placed in a 600 L storage tank at the farm. Half of this was pumped into a 440 L water tank on a utility and diluted with bore water. This was then sprayed onto a 98.8 m² pasture plot. Odour was appreciable but did not last for long. A further 440 L of water was applied to wash the material from the grass blades. This process was repeated with the remaining half of the material on a plot of growing canola. The plot area was set to give a nitrogen application rate of 50 kg N/ha based on advice from the farmer and the local fertiliser supplier. Applied phosphorus and potassium on the urine/leachate plots was 4.85 kg P/ha and 34.6 kg K/ha of . Two control plots were fertilised with chemical fertiliser to give similar loading rates and these had 440 L of water applied to wash chemical from the plants. Two control plots were also used. Soils on the trial areas were tested prior to and after the trial and results will be reported in the final report. The response of the canola was determined by counting pods and seeds per pod, by measuring plant heights and by weighing the crop. Response of pasture was measured by cutting and weighing. There appeared to be a visible and measureable response on both the pasture and canola with the urine/leachate canola plot showing a statistically significant response compared to the control plot and possibly the chemically fertilised plot.

The calculated sodium absorption ratios are approximately 20 for leachate and 120 for urine. There was no obvious impact on the plants or soil in the agricultural trial from this. The sodium load applied was only around 140 kg/ha which is probably less than is applied annually on most irrigation plots.

The results from the agricultural trial indicate that application of urine and leachate to growing canola and pasture as fertiliser is feasible.

The materials were easily collected, transported and applied. Figure 7 shows the canola plot at the conclusion of the trial.



Figure 7: Urine-fertilised canola plot on final day of trial (day of harvest). Tape is 1.2 m high.

User Survey Results

Two user surveys have now been completed. The first, prior to opening of the toilets, indicated a low level of knowledge of composting toilets but considerable agreement that the water and resource-conservation benefits made sense. There was a significant indication that some people (more females than males) would not use the toilets as they regarded them as inferior or undesirable. The second survey showed that only around 25% of students and staff have used the toilets (17% of females and 35% of males). However, the majority of those using the toilets have found it either not as bad as they expected or were pleasantly surprised by the experience as indicated in Figure 8. Many students indicated that they did not use the toilets because smokers use them. This is a significant confounding factor in the overall project that is not related to the type of toilet but the location in the school and the behaviour of students.

When you first used the toilets please indicate your reaction and feelings by circling which of the statements below most closely matches your reaction:

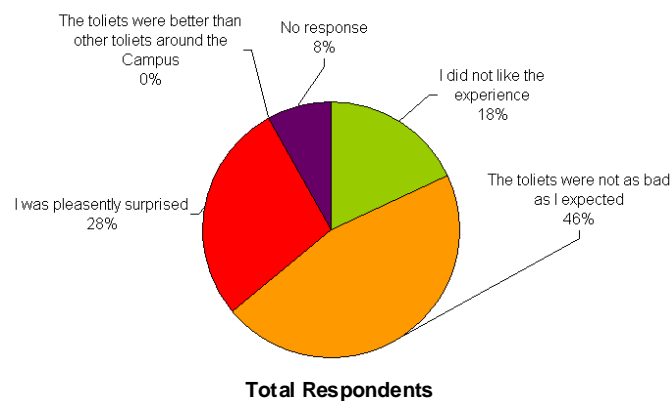


Figure 8 User Reactions from the Second User Survey

Conclusions

The overall conclusion from the trial so far are that urine-separating dry composting toilets of the type installed at Maryborough are an acceptable, safe and effective sanitation option for a school and for wider application. Water is saved and resources can be recovered, probably for no additional energy use compared to conventional sewerage. Odour is effectively contained by use of fans to the extent that the toilet rooms have no odour. The pans can be kept clean readily and absence of flushing does not make the insides of the pedestals unpleasant. Urine and leachate can be applied to growing crops with benefit. Improvements could be made to the design to reduce cost, energy use for fans and to simplify the system. It is probable that, with urine separation, composting in-situ will be difficult to achieve as solids are rapidly desiccated. This makes it doubtful that the costly greenhouse structure provided is necessary. One simple option would be to provide only one or two small bins for solids from each pedestal and to remove desiccated solids regularly to a central controlled composting facility. This would significantly reduce the cost of below ground equipment and structures and probably give better results in terms of fly, odour and health risk control. Much needs to be done for such toilets to gain wide acceptance by users. Guidelines and regulations need to be developed to provide for beneficial use of the recovered resources.

Reference

GHD, December 2003, Composting Toilet Demonstration Feasibility Study, Report to the Smart Water Fund, Victoria, can be downloaded from GHD's website using the following link:
http://www.ghd.com.au/aprixpublishing.nsf/Content/CompostingToilets_prj.