# 1. Introduction

This report is the final report for this project on completion of Milestone No. 6. It consolidates results from the urine-separating dry composting toilet trial at the Maryborough Education Centre.

The project originated when the Department of Education and Training engaged GHD to prepare a report in February 2005 (Stage 2 Maryborough Education Centre – Feasibility of Composting Toilets in Schools) on the feasibility of using urine separation and composting toilets in schools, partly as a result of suggestions from the community committee involved in establishing a new consolidated campus at Maryborough. The project also provided an alternative demonstration to that proposed in an earlier report by GHD to the Smart Water Fund "Composting Toilet Demonstration Feasibility Study" (GHD December 2003) which investigated, in considerable detail, the application of urine-separating dry composting toilet technology and proposed a trial in a multi-storey urban apartment complex. However, the developer of the complex proposed for this demonstration decided not to proceed with the trial of urine separating dry composting toilets.

As a result of this previous work, six urine-separating composting toilet pedestals and two waterless urinals were installed at the secondary school Science/Arts block at the new Maryborough Education Centre. The secondary section of this school is designed for a total of around 1000 students and staff.

GHD sought and, in 2006, received funding from the Smart Water Fund Round 3 to assist with the installation and monitoring program costs for the project.

The new school and the trial installation commenced operation on 18 April 2007 and previous milestone reports have set out:

- Milestone 1 – July 2006: Summary of reports completed and outline of project purpose. Detailed project plan and completion of system design, detailed investigation and monitoring program.
- Milestone 2 – April 2007: Completion of procurement, installation and commissioning including project costs.
- Milestone 3 – October 2007 (resubmitted December 2007): Work completed to train and educate students, cleaners and staff. Communication of the existence of the toilets to the school community and other interested visitors, including results of the user survey completed before commissioning.
- Milestone 4 – November 2008: Commencement of the agricultural trial including documentation of the arrangements and monitoring. Preliminary planning completed to identify area requirements.
- Milestone 5 – November 2008: Monitoring, reporting and communication of Year 1 trial results

The report produced for Milestones 4 & 5 also communicated the majority of the agricultural trial results.

The Milestone No. 6 report aims to provide answers to key research questions that were posed in the application for funding and the project plan before the installation was designed and commissioned. These key research questions (and answers, in brief) are listed in Appendix A. This final, Milestone 6, report includes all key information in the previous Milestone Reports updated and revised as a result of the completed investigation work.

# 2. Objectives, Goals and Measures of Success

The project objectives as set out in the Round 3 Smart Water Fund application were to demonstrate, report and publicise quantitative outcomes of this demonstration in terms of:

- User acceptability;
- Low health risk;
- Water saving and resource conservation benefits;
- Costs; and
- Design details.

In the funding application document, it was stated that the project would be completely successful if:

1. The project is delivered at not more than 25% above initial capital cost estimates (in terms of additional costs when compared with conventional toilets).
2. The facility operates for two years.
3. The majority of staff and student users consider the composting toilets/urine separation system to provide an equivalent or better sanitation method than water flush toilets and no user refuses to use the toilets.
4. There are no odour complaints.
5. There are no incidents related to injury or disease.
6. Insect breeding can be managed and is demonstrated to not cause an increased health risk when compared to conventional toilets.
7. Operating and cleaning costs are no more than 25% above those for conventional toilets.
8. 18 months of beneficial use of residues can be demonstrated in terms of crop yields being within 5% of yields from chemically fertilised crops and no incidents of increased health risk to workers are identified.
9. The project receives interest in terms of visitors coming to the school and a good response to published papers (based on web downloads of the report, enquiries to participants' websites and attendance at any presentations).
10. Data is collected on water use and residue production for the composting toilet building over two years (expressed in terms volume/mass per user) and comparative water use data for the other buildings is also collected over at least 1 year.

As low usage of the toilets meant that there was an insufficient amount of residues available for a meaningful trial until September 2008, the agricultural trial period was adjusted to 3 months instead of 18 months. In addition, the original investigation plan involved application of a mixture of compost, urine and leachate to both pasture and crop trial areas. As only a limited amount of desiccated faecal matter was collected during the trial, solids were excluded from the application.

On completion of the project in April 2009, it can be concluded that, of these criteria for success, numbers 2, 3, 4, 5, 6, 7 and 9 have been met. Criterion 1 was not met, as the capital cost of the installation was high for reasons beyond GHD's direct control. Criteria 8 could not be met although one use of collected urine and leachate was completed. Criterion 10 was not fully met as usage could only be roughly estimated. Thus the project was a partial success based on these criteria.

In addition to the above objectives and criteria, the first Milestone Report (Milestone 1, July 2006) outlined key research questions that the project investigations aimed to answer. The questions were developed in order to assist with determining the details of and equipment needed for the monitoring and investigation program. Whilst the original objective was to answer all of the sub-questions, the 1st Milestone Report also emphasised that this may not be possible either due to time or practical limits.

The key research questions are set out in Appendix A together with the answer or status of the question on completion of the project and references to other sections of the report where further details are presented. In summary, whilst many of the questions were satisfactorily answered, the low usage of the toilets and the inability to establish a usage counting system at the school meant that a number of questions could not be answered and will remain for future investigators to consider.

# 3. Previous Investigations and Outcomes

## 3.1 GHD Report to the Smart Water Fund, 2003

The previous project for the Smart Water Fund (GHD 2003) assessed the feasibility of composting toilets for use in a high-density residential setting. The report reviewed a considerable body of information on urine separation and composting and summarised much useful information from this review.

This report identified several knowledge ‘gaps’ in relation to composting toilets in a residential setting, namely:

» Energy use compared to conventional sanitation;

» Quantity and value of residues;

» Acceptability to users;

» Regulatory uncertainty;

» And the risk of flies.

Despite these knowledge gaps, this report concluded that use of urine-separating dry composting toilets in new dense urban developments could be economic if overall system costs were considered included costs savings in the necessary smaller sewerage system for grey water and value of fertiliser saved by reuse of residues. In addition it was concluded that energy use for such sanitation may be no more and may well be less than for a conventional system once energy savings in the sewerage system and embodied energy in fertiliser saved are included. A demonstration project was outlined and recommended for a multi-storey inner-urban apartment but this did not proceed.

## 3.2 GHD Report to the Department of Education and Training

In a report to the Department of Education and Training (now the Department of Education and Early Childhood Development) that assessed the feasibility of composting toilets at Maryborough and in schools in general (GHD 2005) some key conclusions relevant to this investigation were:

» There is limited reliable data on quantities of compost and urine produced per person and what data there is gives wide ranges and incomplete analyses of constituents.

» For 14 pedestals and 6 urinals in the Arts/Science centre at Maryborough (greater than the number actually installed), the additional capital cost over conventional toilets, assuming the building design was carried out to best suit composting toilets, would be around $100 000 to $130 000 or $5 000 to $6 500 per fixture and additional annual operating cost would be $100 to $400 per fixture. For a new slab-on-ground building designed for conventional toilets, additional capital cost per pedestal was estimated to be $12 000 to $16 000.

» Energy use of the composting toilet installation would be equivalent to or lower than the total energy use of conventional sanitation.

» School indoor water use could be reduced by 60% if dry toilets were used exclusively.

» School pollutant loads to sewer could be reduced by between 45% and 87% if dry toilets were used exclusively.

» A comparative risk assessment of composting toilets versus conventional sanitation identified the following low to moderate, and moderate risks as specific to composting toilets and therefore requiring investigation of the most appropriate specific risk management actions:

   1. Disease transmission to users by flies
   2. Disease transmission to cleaning or maintenance staff by flies
   3. Cleaning staff contact with faecal matter on pedestals
   4. Maintenance worker contact with urine or leachate during unblocking of pipework
   5. Risk of a negative perception or damage to the school reputation arising from poor operation, negative reaction of users or deliberate negative publicity
   6. Risk of difficulty in obtaining approvals for the installation or for residue reuse
   7. Higher capital and operating cost compared to conventional sanitation

» The additional cost of composting toilets may be justified by overall ecological benefits arising from resource recovery, water saving and possibly lower energy use.

» Whilst the risk and consequences of vandalism or misuse was assessed as no higher than for water flush toilets, the risks are different and there is some concern that student users in particular may cause significant operational problems.

» Residues can be safely used in dry land agriculture.

# 4. Approval, Design, Construction and Commissioning of the Demonstration Installation

## 4.1 Introduction

The secondary section of the Maryborough Education Centre caters for about 1 000 students and contains five student toilet blocks plus staff toilets. Currently there are around 800 students and 113 staff in the secondary section of the school. The primary section of the school has its own toilets but receives its water supply via the same water meters as the secondary section. There are currently around 450 primary students and 57 staff meaning that there is a total of 1370 students and staff on the whole site.

The waterless toilet block in the secondary section, housing six Rotaloo® urine-separating pedestals connected to 3 Rotaloo® Maxi 2000 composters and including two waterless urinals, was commissioned when the school was opened in April 2007 on the first day of the second school term. From that date up to the last visit by the study team on 6 May 2009, this toilet block had been open for a total of 313 days out of a total of 417 days the school was open during this period. The composting toilets were closed by school staff on occasions for several reasons: a long closure due to flooding of the basement that caused the leachate collection tank to float and break inlet pipework and three short periods due to vandalism. Whilst the vandalism did not damage the working of the system significantly, the school staff considered that closure was the best means of managing the problems at the time.

## 4.2 Approvals

Current guidelines and regulations in Victoria (and Australia) do not address either urine separation or off-site use of residues on agricultural land surfaces, particularly if, as in this case, the proposal was to apply to the land surface rather than to bury the residues. The only relevant guidelines are in Victorian Environment Protection Authority (EPA) approvals for use of specific models of composting toilet equipment for domestic use which require that any compost removed be buried on site under at least 150 mm of soil and that the area not be used for a period before growing of food crops.

This absence of clear guidelines meant the approval process for the installation involved several steps. Health risks were extensively researched and presented, along with details on the proposed agricultural trial and monitoring, to both the EPA and the municipal Council (Central Goldfields Shire Council). The EPA advised that the composter type proposed was on its approved list, that this approval extended to use in schools and that it would have no objection to the trial, provided a number of conditions were met: the agricultural use of residues complied with published requirements for application of biosolids; the Chief Veterinary Officer of Department of Primary Industries had no objections; and the municipal Council approved the installation and agricultural use on the nominated farm.

The Chief Veterinary Officer was contacted and had no objection provided no beef cattle or pigs were kept on the pasture to be used for disposal. Council required that a formal application and fee be submitted as for a septic tank permit application (although there are few similarities with a septic tank) and also expressed some 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 sell sheep, as farmers must complete a statutory declaration to confirm the sheep they are selling under the National Livestock Identification System have not grazed on contaminated pastures (this largely relates to pesticide application rather than the likely components in residues from the trial).

## 4.3 Assumed Typical Loads in Urine and Compost

The development of the project and installation design was based on work reported by GHD in 2003. Estimates of typical per-capita loads of urine and compost were made based on a literature review and these are set out in Table 1. Derived loads expected from usage by 200 students and staff are set out in Table 2. This estimate of 200 users was based on an assumption that with around 1000 students and staff and 5 toilet blocks in the secondary school, around 200 students and staff would be likely to use the toilets in any one day. The contribution from each person was assumed to be 30% of the daily load of excreta from an adult. It should be noted that this is equivalent to assuming that 30% of daily adult urine production will be contributed by each of the estimated 200 users and that only 60 of the 200 users are likely to defecate in the toilets on any one day.

## 4.4 Design and Construction

The female toilet has four pedestals and the male toilet has two pedestals. There are two waterless urinals in the male toilets and these drain directly to the urine tank. The separate collection of urine keeps the compost drier and also reduces the nitrogen-to-carbon ratio to a more optimum value for composting. GHD earlier research indicated that the drier compost achieved with urine separation should be more permeable to air than wet compost and this was expected to assist the composting process. A simplified cross-section of the urine-separating dry composting toilet installation is shown in Figure 1.

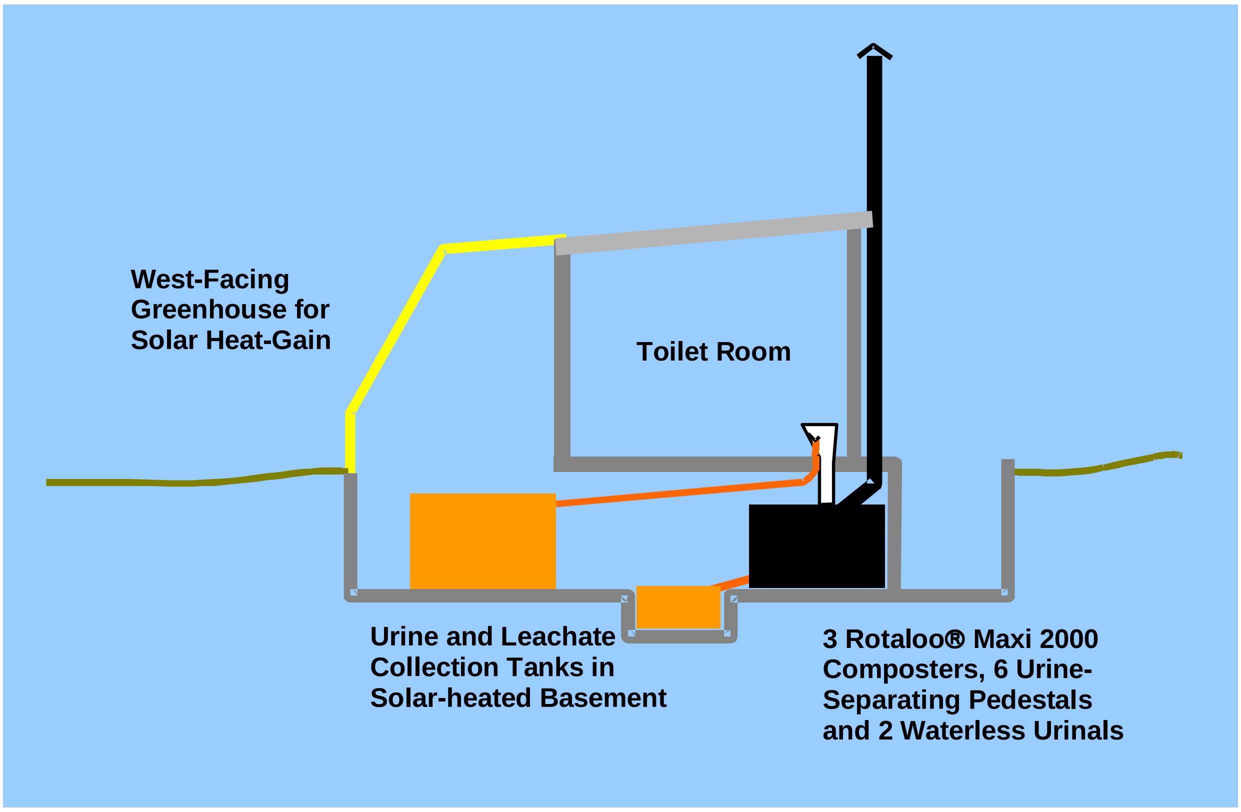


**Figure 1 Cross-section of installation**

## Table 1 Adopted Adult Daily Loads of Constituents of Excreta

| | | Adopted Confidence Ranges and Likely Order of Magnitude Values | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| All values in g/capita.day | | Urine | | | Faeces | | | Paper | Total Load | | | |
| | Source | Min | Max | Adopted | Min | Max | Adopted | Adopted | Min | Max | Sum of adopted component values [5] | Adopted |
| | Volume (L/c.day) | 0.5 | 2 | 1.2 | 0.07 | 0.4 | 0.18 | 0.02 | 0.4 | 1.7 | 1.4 | 1.4 |
| Component | $BOD_5$ | 1.8 | 13.6 | 7.5 | 6 | 18 | 11 | 1 | 12 | 40 | 19.5 | 25 |
| | COD | 5.4 | 30 | 15 | 19 | 55 | 33 | | 32 | 86 | 48 | 50 |
| | TN | 3.6 | 16 | 10 | 1 | 2 | 1.2 | | 5.9 | 18 | 11.2 | 11 |
| | TP | 0.4 | 2.5 | 1 | 0.1 | 1.7 | 0.5 | | 0.6 | 4.2 | 1.5 | 1.5 |
| | K | 1 | 4.9 | 1.5 | 0.2 | 1.3 | 0.7 | | 1.5 | 6.1 | 2.2 | 2.2 |
| | Na | 2 | 4 | 3 | - | - | | | 2 | 4 | 3 | 3 |
| | Ca | 0.15 | 2.2 | 0.3 | 0.67 | 1.4 | 1.1 | | 3 | 4.5 | 1.4 | 1.4 |
| | Mg | 0.06 | 0.2 | 0.2 | - | - | 0.15 | | - | - | 0.35 | 0.3 |
| | $Cl^-$ | 4 | 8 | 6 | - | - | | | - | - | 6 | 6 |
| | $SO_4^{2-}$ | 0.6 | 1.8 | 1.2 | - | - | | | - | - | 1.2 | 1.2 |
| | $NH_3$.N | 0.4 | 1 | 0.7 | - | - | | | - | - | 0.7 | 0.7 |
| | Fats | - | - | 0 | - | - | 4.5 | | - | - | 4.5 | 4.5 |
| | Organic Carbon | 1.8 | 11.9 | 6.6 | 13.2 | 33 | 21 | | 19 | 45 | 27.6 | 27 |
| | Organic TS | 0 | 39.1 | 40 | 26 | 58 | 40 | | 59 | 118 | 80 | 80 |
| | TS [3] | 20 | 147 | 70 | 30 | 60 | 44 | 9.966 | 80 | 130 | 124 | 120 |
| | TDS | | | 70 | | | 14 | | | | | 85 |
| | SS [4] | - | - | 0 | - | - | 30 | 9.06 | - | - | - | 35 |

**Table 2 Estimated Loads of Compost and Urine from Arts Science Building Demonstration assuming 200 Users/day at 30% of Adopted Adult Loads**

| Component | Raw g/d | | Losses % | | After Losses g/d | | | Yearly Loads kg/yr | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Faecal+Paper | Urine | Faecal + Paper | Urine | Faecal + Paper | Urine | Total | Compost | Clean Urine (assume 60%) | Leachate* | Total |
| Total Nitrogen | 35 | 288 | 10% | 10% | 31 | 260 | 291 | 20 | 60 | 30 | 110 |
| Total Phosphorus | 14 | 29 | 0% | 0% | 14 | 29 | 43 | 10 | 10 | 0 | 20 |
| Potasium | 20 | 43 | 0% | 0% | 20 | 43 | 63 | 10 | 10 | 0 | 20 |
| BOD | 1 212 | 381 | 1 | 0 | 909 | 362 | 1 270 | 400 | 80 | 40 | 260 |
| Organic Carbon | 606 | 190 | 25% | 5% | 454 | 181 | 635 | 200 | 40 | 20 | 260 |
| Total Salts | 606 | 1 817 | 0% | 2% | 606 | 1 781 | 2 387 | 300 | 400 | 200 | 900 |
| Calcium | 32 | 9 | 0% | 0% | 32 | 9 | 40 | 10 | 0 | 0 | 10 |
| Magnesium | 4 | 6 | 0% | 0% | 4 | 6 | 10 | 0 | 0 | 1 | 1 |
| Sodium" | 9 | 78 | 0% | 0% | 9 | 78 | 87 | 10 | 20 | 10 | 40 |
| Total Solids | 1 557 | 2 019 | 30% | 2% | 1 090 | 1 979 | 3 069 | 500 | 400 | 200 | 1 100 |
| Water | 4 154 | 34 615 | 93% | 2% | 312 | 33 923 | 34 235 | 200 | 7 400 | 3 500 | 11 100 |
| Total Mass | | | | | | | | 700 | 7 800 | 3 700 | 12 200 |

* Assumes 70% of all urine not collected as clean urine ends up as leachate and 10% ends up in the compost (and 90% of water then evaporates).

" Assumes 10% of the total sodium is in faecal matter.

Figure 2 shows the urine-separating dry composting toilet block and its greenhouse-type west-facing structure. A solar-powered fan system and heat exchanger (a commercially produced unit known as a "Sun Lizard") was installed to assist in supplying warm air to the composters and the solar photovoltaic panel for this is visible between the roof vents. The flat plate on the roof to the left of the solar panel is a black painted heat exchanger through which air is sucked by the solar powered fan. This air entering the solar heat exchanger is drawn from the top of the greenhouse space. Electric fans plus wind-driven fans in cowls on the three discharge vents in the roof maintain a flow of air down through the toilet pedestals and also draw air into the base of the composters from the Sun Lizard (for much of the trial, one of the composters, F2, drew its air supply from the greenhouse space via an electric heater in order to control composter internal temperature. The airflow down through the toilet pedestals prevents odour in the toilet room. Initially, timers controlled the electric fans so that energy use and the cooling effect of air is minimised overnight. Unreliability of the timers resulted in periods of insufficient ventilation during school hours so the fans were then turned on 24 hours per day. The waterless urinals include an oil-filled seal to prevent odour from urine. An in-ground biofilter removes odour from the urine and leachate tank vents. The three pipes stubs pointing up from the ground, on the right in Figure 2 are part of the biofilter and allow for future connection of the roof vents to the biofilter if necessary.

**Figure 2 Outside view of structure from the West**

Three Rotaloo® Maxi 2000 composters in the basement (shown on the left in Figure 3) connect directly to two ceramic urine-separating pedestals. Each composter contains eight triangular 50 kg capacity HDPE compost bins on a carousel. Two bins are active at any one time. The 2.7 kL PVC leachate tank (centre), in which any unseparated urine (or added water) that has drained through the holes in the bottom of the composting bins is collected, is in the floor. The 4.3 kL HDPE urine tank, to which separated urine flows via PVC pipework, is located opposite the composters (on the right).


**Figure 3 View inside basement**

The plumbing sub-contractor completed the installation to a high standard, with considerable flexibility and cleaning access built in to the plumbing and tankage.

As previously indicated, the composters and tanks were sized based on the assumption that approximately 200 students over normal school hours would use the toilet and that, whilst at school, they would, on average, contribute 30 percent of published daily urine and faecal loads from adults. This equates to an expected student daily contribution of around 360 mL of urine and around 72 g of wet faecal matter and toilet paper containing 12 g of dry solids (although actual usage for any one defecation would be close to the adult load, say three times this). It was estimated it would take 0.5 to 1 year to fill the urine and leachate tanks and around 1 to 2 years to fill all 24 compost bins. During the trial, usage has been estimated by assuming each use by a student contributes between 150 mL and 360 mL of urine and actual use has averaged fewer than 6 student uses per day, with negligible use by staff. Usage is discussed in Section 5.2.

Design documents for the facility as presented in Milestone 1 Report are attached in Appendix B.

The installation was completed largely in accordance with these documents but substantial additional work had to be carried out in a number of areas related to the excavation of rock and drainage of the basement, as well as air ducting and pipework.

There are many features of the design that have worked very well including:

» The toilet room layout has been effective and the finishes have been relatively easy to keep clean.

» The basement layout has worked well with the exception of the low headroom around the leachate tank and composters.

» The plumbing system has worked without fault.

» The materials both in the tanks and pipework and the building have not suffered from corrosion.

» The composters, drop ducts and pedestals have not been damaged (despite some attempts) and have not required any special cleaning.

» The pedestals are easy to keep clean.

## 4.5 Commissioning

GHD spent a day at the site on 12 April 2007 with a representative from Environment Equipment (the Rotaloo® supplier). The following tasks were completed on that day:

» Final inspection of the installation and listing of minor defects

» Fixing of notices and labelling of tanks

» Set up of a use counting letter box system

» Calibration and making of tank dipsticks

» Placing geotextile and pea straw in compost bins to make them ready for use

» Training session for the cleaning and maintenance contractor, which also outlined monitoring tasks and explained the log sheets

» Weighing of all compost bins (with and without geotextile and pea straw). Empty compost bins weighed between 9.95 and 10.40 kg (with an average of around 10.25 kg) and geotextile and pea straw added around 0.1 and 0.15 to 0.2 kg to this weight giving a total mass of bin, geotextile and pea straw at commissioning of typically 10.5 kg.

It was noted that building contractors or school staff had made some use of the urinals and there was considerable volume in the urine and leachate tanks. Unfortunately, it later turned out that this was probably water (presumably used for testing the tanks) rather than urine. It would have been desirable to pump this volume out of the tanks as it diluted the urine and leachate collected. At the time the volume was noted as being small and was assumed to be urine, and since substantial use was expected, no action was taken.

Photographs of the installation on completion of commissioning are included in Appendix C.