Appendix A

Key Research Questions

No.	Key Research Question	Response
On-site installation and its use, cleaning and maintenance		
1	***Can flies be adequately controlled to a point where health risk is minimal and nuisance is eliminated?***	Flies were observed on one occasion only. With greater use and more active composting it is considered that this installation may still suffer from fly nuisance with access via the poorly sealed lids or unscreened vents being the main routes. Better fitting lids, fly screening of vents using finer than normal mesh, fly screening of the toilet building and user training may be sufficient to control fly breeding. Refer Section 5.9.2.
1.1	What types of flies occur?	Small fruit flies (Probably *Drosophila melanogaster*)
1.2	What conditions/events increase numbers of flies?	Toilet seat lids left open. Lack of screens over vents. Poorly fitting doors and seals on the composters. Probably warm, moist compost.
1.3	Where are flies a problem, inside the toilet room, outside, within the sub-floor area?	Under toilet seat lids and in compost bins and composters. There is a risk of presence in the toilet room and other parts of the building.
1.4	What are workable means of controlling flies, e.g. fly traps, screening, composting temperature, use of insecticides, training to keep pedestal lids closed?	» Closing toilet seat lids » Fly-proof seal on toilet seat lids » Screens on composter induct and educt vents » Rigid frame around composter access hatch » Desiccating rather than composting the solids, as was achieved in this study, is an alternative effective means of fly control.
2	***Can the installation be operated without complaints of any kind (odour, flies, cleanliness, aesthetics or just related to perceptions) by users, cleaning staff, maintenance staff?***	The toilet rooms are generally kept odour-free and urinals and pedestals are reportedly easily kept clean. Refer Sections 5.8 and 6.3.
2.1	What complaints are made and what is the frequency?	» One odour complaint each inside and outside of toilet room » Surveyed users complained about graffiti, cigarette smoke and “unconventional” toilets
2.2	What operating conditions correlate with particular types of complaints?	Odour complaints due to ventilation system failure resulting in odour inside the toilet room, and still conditions resulting in odour from vent stacks

No.	Key Research Question	Response
2.3	Do spiders ever enter or emerge from the pedestals?	No spiders have been noted inside the composters or toilet pedestals but this probably relates to the absence of flies since other installations report extensive spider web formation in ducts.
3	***Do users develop a view that urine-separating composting toilets are superior to conventional water-flush pedestals?***	Some users were pleasantly surprised by the toilets and some indicated they appreciated that there may be environmental advantages of saving water and recovering nutrients. The cleaner considered that there was less smell in the toilet room than in other toilets and that they were as easy or easier to keep clean. Refer Section 6.3.
3.1	What views do users have prior to being provided with information and training?	» Students did not have much knowledge/had rarely used waterless toilet systems » Staff had better knowledge of/had previously used waterless toilet systems more often » More students than staff were deterred from using the toilets due to the unconventional nature
3.2	What views do users have once they have been provided with information and training but before becoming regular users?	Those not using the toilets regularly reported misuse by other students as a reason for limited use, such as use of the toilet room for smoking.
3.3	What views do regular users have?	Most of those who had used the toilets found them to be not as bad as or to be better than expected. The investigators and cleaners noted that there was consistently no smell in the toilet rooms.
4	***Do users develop a view that waterless urinals are superior to conventional urinals?***	No evidence that such a view developed. User Survey No. 2 did not refer to waterless urinals and waterless toilets separately. Refer to Question 3 above for responses regarding waterless toilet systems in general. No complaints were made about the urinals specifically. Refer Section 6.3
4.1	What views do users have prior to being provided with information and training?	Of the male respondents (staff and students), 39% had used a waterless urinal previously, 36% had not used one previously and 25% were unsure.
4.2	What views do users have once they have been provided with information and training but before becoming regular users?	Refer to Question 3.

No.	Key Research Question	Response
4.3	What views to regular users have?	Refer to Question 3.
5	***Can the installation be cleaned and maintained with no appreciable risk to health of cleaning and maintenance staff and users?***	Definitely yes in this case, although if usage had been higher some additional fouling of the pedestals would be expected. The cleaner found the urinals and pedestals were easy to keep clean. Pedestals in particular did not become fouled. The drop pipes from pedestals did not become fouled. Refer Sections 5.8 and 5.9
5.1	What regular cleaning and maintenance activities (eg pedestal and urinal cleaning, urinal seal servicing, bin, urine and leachate pipework maintenance) present a greater health risk than water flush toilets?	The toilet room and pedestal/urinal cleaning undertaken by the cleaner has not appeared to present any greater health risks.
5.2	Can the installation or procedures be developed to reduce the risks to the same level as with water-flush toilets?	The cleaner used the same method as for other toilets but did not put water down the pedestals or urinals for cleaning. No greater risk was noted than with conventional toilets.
5.3	What is the best system and materials for pedestal and urinal routine cleaning?	The toilet rooms were initially cleaned by using a 1:5 vinegar to water solution to wipe over pedestal seats and surfaces, waterless urinals and other surfaces. More recently, a proprietary scented cleaner has been used in all toilets.
5.4	Do cleaning and maintenance staff perceive a greater risk?	The cleaner has had no difficulty keeping the urinals and pedestals clean and has not indicated a perception of greater risk.
5.5	What is the best equipment and materials to provide for users to clean the pedestal after use?	Cleaning has been undertaken by the sub-contractor employed by the school rather than by users. It is unlikely that school students would use cleaning equipment and in any case it is not considered necessary to provide it since pedestals do not easily become fouled.
5.6	What is the rate of scale build-up in the Rotaloo® base, leachate pipework and leachate tank and what is the chemical composition and physical properties of this scale?	Only limited scale build-up was observed and the scale was not difficult to remove. It is probably that magnesium ammonium phosphate (struvite) is the main scale material. The bases of the composters showed some scale. The urine pipework showed little scale but some minor sand-like sediment build-up. The material was not analysed. Refer Section 5.5.1

No.	Key Research Question	Response
5.7	What is other solids (including hair) build up in the urinals, urine bowl, pipework and urine tank and what is the chemical composition and physical characteristics of the solids?	No significant hair build-up noted anywhere. Litter items were a significant and ongoing problem, as they had to be regularly removed from compost bins to avoid degradation of the quality of the collected solids. No build-up in flexible pipework from pedestal urine bowls was noted, no significant build-up in the urine pipework generally. Leachate pipework could not be inspected without dismantling but there were no blockages. There was some scale in the base of composters so some scale in leachate pipework is also likely. There were solids in both the urine and leachate, generally in flake form, which may be magnesium ammonium phosphate scale. No analysis was carried out. Refer Section 5.5.1
5.8	What is the best cleaning approach for the base of the Rotaloo®, leachate pipework and leachate tank?	Cleaning was not required. Others have found an acid soak is necessary periodically in heavily used installations.
5.9	Rate of build-up of spider webs, headloss impact and best cleaning system for spiders?	No spiders or webs have been noted.
6	***Do cleaning and maintenance staff object to specific tasks that cannot be avoided by design?***	No objections have been reported.
7	***What should a nuisance-free, safe and energy-neutral installation cost and how much higher is this cost compared to conventional toilets?***	It is unlikely that urine-separating dry composting toilets can be installed for the additional cost estimated by GHD in 2003 which was around 6 600 AUD and it would be safer to estimate on the basis of around 10 000 AUD to 15 000 AUD per fixture. However, with ongoing development and wider use this cost differential should come down. Note that a conventional fixture costs around 5 000 AUD per fixture. Refer Section 9.1
7.1	What is the capital cost of the installation in total, including design cost and what are the components?	Total capital cost of installation is estimated to be approximately 335 000 AUD. Refer Section 9.1
7.2	What is the cost, including design, of additional features, flexibility and monitoring equipment included for the trial that would not be part of a normal installation?	Special monitoring equipment, an electric heater and signage that would not be required in a normal installation cost a further 7 500 AUD.

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7.3	What changes and estimated savings could be made in a future design without compromising performance?	» Reduced structural and drainage costs if building is constructed on sloping ground on piers rather than on rock as a slab-on-ground structure. » Simplification and reducing size of greenhouse structure or not building this structure. » Basing the installation on urine-separating desiccating toilets. Refer Section 12.2.4
7.4	What would the capital cost of a conventional water flush toilet installation be?	Cost estimating data indicates that capital costs for a conventional water-flushed toilet installation are typically around 5 000 AUD/fixture including associated in-house plumbing. Costs per conventional toilet were not available for the school. See Section 9.1
7.5	What was the operating and maintenance cost for the installation for a year and what was the total usage?	These costs were not available and would be misleading due to the low usage.
7.6	What operating and maintenance costs should be deducted as they relate to the trial?	As for Question 7.5
7.7	What savings could be made in operating and maintenance cost without compromising the level of service to users?	The regular removal of litter and addition of water to the composters was an avoidable cost in different circumstances.
7.8	What would be the operating and maintenance cost of a conventional water-flush toilet installation at similar usage level?	No data was obtained.
8	***What is the minimum total energy use for the installation compared to conventional water flush toilets, including energy use for dealing with residues?***	The estimate in GHD (2003) was generally supported by this work although fan energy usage was at the high end assumed in the earlier work. It is concluded that the best available current estimates are that urine separating dry composting toilets and associated residue transport may not consume any more energy than conventional water-borne sanitation and associated sewage treatment. Refer Section 10.
8.1	How many kW.hr/week of electricity do the fans on the Rotaloo$^{®}$ s use?	The fans consumed 66 W or 11 kW.hr per week.

No.	Key Research Question	Response
8.2	What is the minimum ventilation rate and kW.hr/week use to prevent odour in the toilet room?	When the fans were operated for 13.75 hr/day, adequate odour control was achieved. This would equate to 6.3 kW.hr per week for the 6 pedestals.
8.3	Could more energy-efficient fans be used and if so what optimum energy use for ventilation could be achieved?	It is considered that a power of 4 W per pedestal as assumed in the GHD 2003 report would be feasible since, with 13.75 hrs of fan operation, the installation ran at the equivalent of 6.3 W continuous per pedestal. There was no odour in the toilet room when fans operated and a lower airflow should be possible.
8.4	What other electricity or gas use is necessary to maintain good performance?	Heating of Composter F2 did not appear to improve performance. No gas was used. See Section 5.4
8.5	What is the total energy use for operating and maintaining the installation, including transport and use of residues what usage level does this energy use support?	No additional information was obtained that would add to the estimate made by GHD in 2003 Refer Section 10.
8.6	What is the total energy use of water flush toilets for the same usage level in the Maryborough situation?	As for Question 8.5
9	***How much water is saved by waterless sanitation in a school setting?***	The best estimate is that around 1.7 L/use is used for hand washing in a dry composting toilet compared to around 4.2 L/use for flushing and hand washing in a conventional toilet. However, the data is not very reliable, as usage of the toilets could not be counted. The data does suggest that not all students and staff use the flush or wash their hands in either type of toilet. These dry composting toilets also used water to keep the compost moist so as to control fire risk. This removed any water saving because of the low usage of the composting toilets. At normal usage, equivalent to that in the conventional toilet, this additional water would have been either unnecessary or insignificant. Refer Section 5.7.
9.1	What is the water usage for flushing toilets in a conventional toilet installation for the same usage level as the composting toilet and waterless urinal installation?	Measured use for flushing and hand washing in conventional toilets at the school could only be roughly estimated based on assumed use and appeared to be a surprisingly low 4.2 L/use. Around 8.5 L/use would be expected.

No.	Key Research Question	Response
9.2	What is the total school water use from all sources in aggregate and expressed per student/staff member for toilets, hand basins, canteen, laboratories, irrigation and other uses and how does it vary seasonally and with school usage?	Total water use for all purposes (other than irrigation which is separately supplied by rain water and tankered-in water at this school) was 7.1 L per student and staff member per day. Seasonal variation was not measured but would be significant due to the use of evaporative cooling throughout the school.
9.3	What is the impact of composting toilets and urine separation on water use for the case of no composting toilets and waterless urinals, the demonstration installation and full conversion to composting toilets and waterless urinals?	If all toilets in the secondary school had been dry composting toilets then around 460 kL/yr of water could be saved out of total usage of around 1 219 kL/yr (based on 200 operating days).
10	***What reduction in sewage loads is achievable?***	Refer Section 5.7.
10.1	What is the sewage flow from the school in aggregate and expressed per student/staff member and how does it vary seasonally and with school usage?	It had been proposed to install a sewage flow meter but this was not possible within the budget available.
10.2	What is the sewage load from the school in aggregate and expressed per student/staff member and how does it vary seasonally and with school usage?	It is likely that the flow to sewer is somewhat below 7.1 L/person per day since some water is used for evaporative cooling.
10.3	What is the impact of composting toilets and urine separation on these loads for the case of no composting toilets and waterless urinals, the demonstration installation and full conversion to composting toilets and waterless urinals?	No additional information was obtained in this study that would change estimates of reductions that are presented in GHD's first report to the SWF (GHD 2003).
11	***What quantities of residues are produced as a function of uses?***	No additional data on this question could be obtained beyond that presented in GHD 2003 since it proved to be impossible to count uses during this study.
11.1	What are the aggregate masses and volumes of compost and urine produced?	As above
11.2	What are the average volumes and masses per student/staff member per school day where student/staff members only use the composting toilet and waterless urinal installation?	As above
11.3	What are the average volumes and masses per usage type?	As above
12	***What is the chemical composition of residue material at the time it is ready for reuse (emphasis on sodium, chloride, total salts, nitrogen forms, soluble orthophosphate, total phosphate and water content)?***	Refer Section 5.3 for urine, leachate and compost.
12.1	What percentages of compost and urine are made up of the following: water, urea, ammonia nitrogen, total nitrogen, total phosphorus, soluble ortho-phosphorus, sodium, magnesium, calcium, silica, zinc, copper, other metals, sulphate, chloride, bicarbonate and carbonate, cellulose fibre, total solids, dissolved solids, volatile total solids, volatile dissolved solids?	Refer to Table 3 for analyses of collected urine and leachate. Refer to Table 4 for analysis of collected compost.

No.	Key Research Question	Response
12.2	What concentrations on a wt percentage basis of key pharmaceuticals are present in compost and urine?	Pharmaceutical testing was not undertaken due to difficulty of finding a suitable laboratory and time and financial budget constraints.
12.3	What counts of key indicator bacteria and ova of Helminths are typical and what is the variation with different operating conditions?	See Table 3 for urine and leachate data and Table 4 for compost. Note that difficulty in finding a laboratory that could undertake pathogen and non-bacterial indicator analyses prevented much of the originally planned analysis.
13	***What is the optimum operating temperature for composting and what degree and method of supplementary heating is necessary?***	The small volume of compost collected resulted in desiccation rather than composting, so no information could be obtained on this question. Refer Section 5.6
13.1	What temperature distribution is achieved in various zones of a batch over a cycle time?	As above
13.2	How feasible in terms of pathogen die-off and odour is letting composters run cold?	As above
13.3	Does compost become too dry (necessitating water addition) due to excessive natural or supplementary heating?	The compost in Composter F2 did appear to be drier than in other unheated composters but the difference was small. Compost in all composters was too dry for effective composting due to low usage and the airflow.
13.4	Is there a correlation between fly breeding and temperatures achieved?	Fly breeding was minimal probably as a result of the desiccated state of the compost.
13.5	How long is a cycle of natural heating and cooling and how does it vary with supplementary heating provided?	No information obtained.
13.6	Is the passive solar heating arrangement provided sufficient to achieve high compost batch temperatures at all times of year?	The passive heating used was only partly successful.
13.7	Could the passive solar heating arrangement be simplified, improved or downscaled in terms of greenhouse cost?	The arrangement was not particularly effective. Simplification and savings should be possible, especially if desiccation is the adopted solids processing route as suggested for this type of installation.
13.8	Is supplementary heating by gas or waste heat recovery from buildings essential to achieve adequate composting temperatures in winter, is it just beneficial or is it not essential?	This cannot be determined as there was no active composting even with heating.
13.9	If supplementary heating is necessary, what heat input and energy use is necessary per Rotaloo®?	500 W of electrical heating for a single Rotaloo® Maxi 2000 unit with 2 pedestals should be adequate.

No.	Key Research Question	Response
14	***Is addition of carbon source (most likely in the form of green hardwood shavings) necessary and beneficial to composting?***	No information was obtained on this question, as compost quantities were too low to allow investigation.
14.1	Does addition of carbon produce higher composting temperatures?	As above.
14.2	Does addition of carbon reduce odour?	The compost desiccated and did not produce odour.
14.3	How do any benefits vary with the amount of added carbon?	No information obtained.
14.4	Does adding carbon improve aesthetics?	No information obtained. The aesthetic issue in this trial was the presence of litter in compost bins.
14.5	What is the cost of optimum amounts of added carbon including supply, cleaning, and additional cartage?	No information obtained.
14.6	Is operation without added carbon satisfactory in terms of pathogen die-off, odour, aesthetics (down the chute and within the cubicle) and odour?	No information obtained.
14.7	What is the influence of added carbon to quantity, composition and bacterial and ova content of the compost?	No information obtained.
15	***What is the optimum storage temperature for urine and leachate in terms of maximum pathogen die-off?***	Advice from several researchers was to monitor normal indicator bacteria first and only move to pathogens once behaviour of indicator bacteria was understood. Results from an experiment to determine the rate of die-off of bacteria suggest that *E. coli* and Faecal *Streptococci* do not survive for more than a few months in either urine or leachate held at around 20 degrees Celsius. Refer Section 7.11
15.1	What temperatures are achieved in the urine and leachate tanks over a filling cycle?	Temperatures up to around 30 degrees Celsius have been recorded externally at the base of the urine tank. No measurements have been obtained for the leachate tank.
15.2	Is the passive solar heating provided sufficient to maintain an optimum temperature for pathogen die-off?	The record of outlet temperature from the Sun Lizard over the trial shows that temperature did reach 50 degrees Celsius for short periods over summer, which is above the See Section 5.4.4
15.3	Is there evidence of improved pathogen die-off with increasing temperature above ambient?	No information obtained.

No.	Key Research Question	Response
15.4	Does varying storage temperature of urine or leachate influence odour?	No odour was reported in the toilet rooms. Odour noticed when opening the urine/leachate tanks was not observed to change with storage temperature.
16	***How can the overall design be improved?***	Refer Section 12.1
16.1	Is passing the ventilation air from urine and leachate tanks to a biofilter necessary?	Yes, the biofilter did prevent release of urine odour (which was noticeable whenever tanks were opened).
16.2	Is passing the Rotaloo® ventilation air through a biofilter necessary?	Not with an installation where the compost is desiccated. It may be desirable if there is active wet compost but this could not be determined.
Agricultural Residue Use Trial		
1	***What application rates of compost, urine, leachate or a mixture give a similar dry land crop response to normal chemical fertilisers?***	The scale of the trial was too small to make realistic estimates of crop yield.
1.1	What crop yield for the selected crop on similar soils is achieved with normal chemical application, optimum chemical application and with equivalent (in terms of added N and P per ha) applications of a mix of compost, urine and leachate?	As composting of solid material did not take place and there was insufficient compost material to use as a fertiliser, the agricultural trial was limited to the use of a urine/leachate mix (see below).
1.2	What crop yield for the selected crop on similar soils is achieved with optimum chemical application and with an equivalent application (in terms of added N and P per ha) of a mix of urine and leachate only?	The trial was too small in scale to make realistic estimates of crop yield.
2	***What health and aesthetic issues arise with compost and urine collection, transport and application to land and how can risks be reduced to an acceptable level?***	Refer Sections 7.2 and 7.5.
2.1	Can handling, loading, transport and application of compost, urine and leachate be safely undertaken both from a lifting and materials handling and health perspective and how could it be improved?	» There was no spillage during collection or transport of residues. » A fire pump was used to apply the urine/leachate mix to land and this application method did involve exposure to some spray drift. » A preferred application method would be from a trickle bar on the back of the eductor truck (this would probably also generate less odour).

No.	Key Research Question	Response
2.2	Are there odour, fly or other aesthetic problems, where do they arise and how could the problems be reduced?	» During collection no odour was detected outside the toilet building. Minor odour was noted in the basement when the tank hatches were removed. » Some odour was noticeable during hosing of the urine/leachate mix over the plots and the smell remained downwind of each plot for about an hour after application. » Odour could be reduced if alternative method of application was used, as described in 2.2 above.
3	***What is the attitude of farmers to use of compost, urine and leachate on dry land crops?***	The farmer was willing to take further loads of urine/leachate. No compost was used.
4	***What is the current economic value of compost, urine and leachate in terms of fertiliser replacement including savings in embodied and transport energy?***	Refer Section 7.8
5	***What is the comparative cost of collection, transport and application of compost, urine and leachate compared to chemical fertilisers?***	No realistic data could be obtained from this small-scale trial that would change the estimates in GHD 2003.
6	***What issues require further investigation?***	See Section 12.3