Composting Toilet Demonstration

Feasibility Study

EXECUTIVE SUMMARY

Smart Water Fund

BENSONS PROPERTY GROUP P/L

DEMAINE

ENVIRONMENT EQUIPMENT PTY LTD SINCE 1974

GHD in association with Demaine Partnership, Bensons Property Group and Environment Equipment

December 2003

Executive Summary

Scope, Objectives and Outcome of this Feasibility Study

Waterless (or dry) composting toilets have the potential to reduce water use and divert pollutant loads from the sewerage system direct to agriculture.

This feasibility study has investigated:

- technical feasibility;
- costs;
- probable customer acceptance;
- regulatory constraints and
- environmental advantages

associated with the composting toilets with urine separation as an alternative to water-flush toilets. Emphasis has been on application in medium to high population density apartments in the urban Melbourne setting.

Whilst application of dry composting toilets is widespread in low density developments remote from sewerage schemes and whilst waterless urinals are being introduced in a variety of settings, the combination of both technologies in a high density urban environment has only been tried on a limited scale overseas. There is a need for demonstration of the technology in the medium to high population density urban setting because few decision makers with responsibility for sewerage planning have been exposed to composting toilets, composting toilets are rarely if ever considered in planning and there is limited information on rigorous assessment of their advantages and disadvantages.

The Funding Agreement between GHD and the Smart Water Fund for this feasibility study required reporting on:

- relevant government policy frameworks;
- key legal and regulatory risk issues associated with the project and the attitudes regulators may have in relation to the project;
- key technical risk issues associated with the project and how they can be managed;
- responses of potential end-owners of the properties equipped with composting toilets;
- regulatory constraints and contradictions and next steps required to progress the project.

In summary, the study has confirmed that there is an environmental and economic justification for further investigation, including a demonstration project.

Potential Advantages of Dry Composting Toilets with Urine Separation over Water-Flush Toilets

The potential advantages of widespread adoption of dry composting toilets with urine separation are:

- up to about 19% of an average household water usage (up to around 18 kL/c.yr saved out of 96 kL/c.yr currently used by the average Melbourne household) and up to about 28% of domestic sewage discharge would be avoided by eliminating toilet flushing. For the 12 apartments envisaged for the trial this translates to savings of up to 490 kL/yr;

- over 80% of the nutrients, 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;
- even if adoption of composting toilets is limited, the potential 19% reduction in household water usage, 28% reduction in sewage volume, 80% reduction in nutrient discharge, 25% reduction in BOD and 55% reduction in total salts discharged by households to sewer could have a significant benefit in extending the life of water supply, wastewater collection and treatment systems as well as reducing loads discharge to receiving waters, reducing the salinity of recycled water and reducing the mass of biosolids generated at the sewage treatment plant;
- 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. In the case of recycling of grey water for toilet flushing or low flush volumes, the concentrations of pollutants in wastewater, including concentrations of salts, are in fact increased which, in the case of salts, may impact on reuse potential;
- there is no odour in the toilet room;
- overall health risks to householders and sanitation workers are assessed as being no higher than with conventional sewerage;

Separation of urine is a key to improving composting and providing a liquid fertiliser with low health risk and urine separation on its own is receiving attention world-wide as a means of saving flushing water and recovering nutrients. Around 60% of urine can be separated using modern designs of compost toilet pedestals and these designs require minimal change to personal habits. In particular, designs are being developed to allow men to stand when urinating. Habit change to close the lid of a composting toilet after use is important for odour and ventilation control.

Based on review of the international literature, independent assessment of claims made by composting toilet suppliers and data on composting toilets and inspection of a number of composting toilets in Australia, these potential advantages have been confirmed. In addition, the feasibility study has shown that dry composting toilets with urine separation and a road-based transport system for compost and urine may have the potential to reduce energy use for wastewater transport and treatment, or at least not use significantly more energy, provided energy saved in fertiliser manufacture is taken into account and energy use for ventilation and heating associated with the composting toilet can be minimised.

Feasibility of a 12 Apartment Demonstration Site

Whilst this feasibility study concludes that composting toilets with urine separation potentially have advantages over conventional water-flush toilets, no one existing installation demonstrates all of these advantages for urban application, since most are in isolated locations in low population density settings and none have been subjected to rigorous monitoring. Therefore, a carefully designed and monitored demonstration project is considered essential as the next step.

Preliminary design and costing of a demonstration project on 12 two-storey apartments in Flemington has been undertaken in association with the developers, architects and a composting toilet equipment provider.

The developer, with GHD's assistance, has undertaken a customer survey, to which there were some 55 respondents, indicating that:

- 55% would consider purchasing an apartment with a composting toilet and 28% may consider purchasing such an apartment, a total of 83%;
- 76% would consider paying $5 000 more for a water-efficient apartment and a further 18 % may consider paying such an extra sum for a water-efficient apartment, a total of 94%; and
- respondents under 40 indicated a generally higher level of interest than older respondents but there was no significant difference in interest between genders.

Whilst a decision on whether to go ahead with this demonstration project will depend on further market analysis, design development and availability of funding assistance, and whilst potential purchasers may well change their minds when it comes to actually signing a contract, there is an encouraging indication that it would be possible to sell compost toilet-equipped apartments and that there is a demand to be satisfied.

The type of installation proposed for the demonstration will involve two modern toilet pedestals, one on each floor of each of the 12 apartments. The toilet pedestals are arranged in a way that most of the urine will be diverted to a holding tank shared by all 12 apartments. Solids will fall vertically down shafts to one multi-bin rotary composter in a sub-floor space for each of the 12 apartments. This rotary composter design has the advantage that filled compost bins are left to mature for some months after they become full which provides for a high degree of solids stabilisation, inactivation of pathogens and reduction in mass via an aerobic composting process before a person has to remove a finished bin from the composter. Leachate (liquid, including urine, that is not collected, but drains through the composting solids) will drain to a separate storage tank. Removal of a total estimated mass generated of around 11 tonnes/yr of urine and leachate and around 0.7 tonnes/yr of compost, will occur every three to six months by contract collection. Apartment owners will not have to handle the recovered materials although either the body corporate (or possibly and preferably the sewerage authority) will have to administer the removal contract.

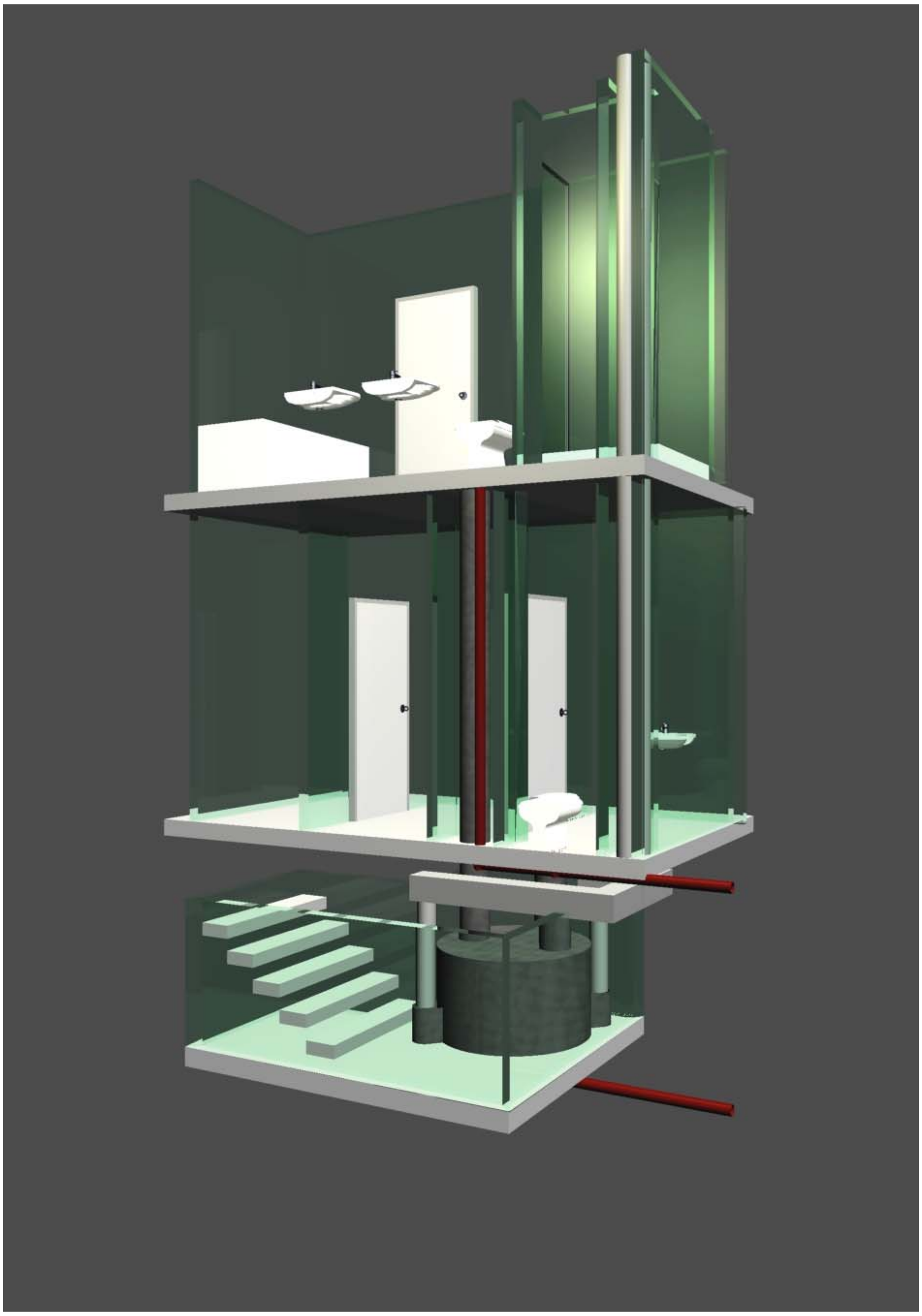
It is concluded that such a trial will involve additional capital costs (compared to standard water-flush toilets) of around $9 500 per apartment, or a total of $114 000 for the 12 apartments. Of this, some $6 500 per apartment or $78 000 for equipment has been specifically included for monitoring, data collection and flexibility in design and operation and would mostly not be required for normal commercial installations in the future. Thus the likely premium to pay for a two pedestal composting toilets in a two storey apartment is around $3 000 compared to standard water-flush toilets.

Consistent with other programs concerning lessening the ecological impact of housing (such as solar hot water installation), it would be appropriate to expect some contribution by Government and other interested parties to this additional cost per apartment in order to support the developer in installing the trial composting toilets. In addition, some reductions in headworks charges for the development would be justifiable. Thus, funding will be sought from various potential sources to offset the additional cost.

Operating costs for maintenance of the composting toilets, and for cartage and disposal of the compost, urine and leachate could be expected to be higher than standard sewerage rates given the small quantities of compost and liquid residues involved with the trial and the need for special transport arrangements. However, calculations indicate that overall operating costs will be similar provided that some reduction in sewerage rates is agreed with the water authority concerned. Significant expenditure on analysis and monitoring including monitoring of water use and grey water quality for the apartment development is proposed and would be part of the funding assistance sought rather than a cost to apartment owners.

Potential cartage contractors have indicated that they do not foresee any difficulties in collection and cartage of the material using a small truck with custom-built tray and containment.

The following figure gives an impression of the proposed arrangement of composting toilets in the apartments.



Proposed arrangement of composting toilets in one of the apartments

The compost chamber would be below the ground floor slab. One toilet pedestal would be located on each floor above the composting chamber. Plumbing to collect urine from each pedestal and leachate from the compost chamber is shown. Note that the access steps for maintenance and removal contractors to the sub-floor space would be shared between two apartments (the adjacent apartment and its composter which would be to the right are not shown).

Agricultural Reuse Trial for Residues

Just as a demonstration is necessary that composting toilets with urine separation are a real and acceptable option for apartments, a demonstration that the nutrient-rich residues can be safely and advantageously used in agriculture is necessary in order to provide a sound basis for decision-making on large scale application of this alternative sanitation approach.

A key benefit of composting toilets with urine separation is that the majority of nutrients in normal domestic sewage can be recovered in a form suitable for replacing manufactured fertiliser. This contrasts with conventional sewage systems where the majority of nutrients are either discharged to receiving waters or in the case of nitrogen, driven off into the atmosphere using electrical energy and, in the case of phosphorus, incorporated into biosolids at relatively low concentrations and low availability to crops.

It is proposed that the 12 tonnes of residue produced annually will be used as fertiliser in agricultural trials, probably on a site within Melbourne Water's Western Treatment Plant under an EPA Research, Development & Demonstration Approval. Melbourne Water has given agreement in principal to provide land. During the trial, alternative receiving sites would be identified for long term beneficial reuse of the residues.

The initial concept for this demonstration project envisaged an extensive and therefore expensive trial on both vegetable and grain crops with comprehensive investigation of crops, soil, groundwater and health issues. Advice from experts on the feasibility study Reference Panel including advice from Agriculture Victoria, led to the conclusion that a less ambitious agricultural trial on dry land grain crops or pasture would be appropriate. Part of the reason for this conclusion was that, even if safety of use on vegetable crops can be shown, farmers are unlikely, for the foreseeable future, to use the human excreta products on anything other than grains or pasture.

The proposed agricultural trial would be designed by Agriculture Victoria, with input from health specialists. Two hectares of land would be sufficient and it is estimated that set up and operation of the trial for two years with a final report would cost $300 000. The more comprehensive agricultural trial originally envisaged would have cost at around $700 000.

Key aspects of the agricultural trial would include:

- baseline monitoring of soils and groundwater and reporting at the end of the 2-year trial period on any changes in soil or groundwater due to application and possible long term impacts;
- investigation of total and available nutrients in the urine, leachate and compost and plant response;
- regular monitoring of bacterial levels, possibly indicators of faecal contamination such as cuprostanol and spiking trials using attenuated pathogen strains to obtain data on the likely fate of pathogens;
- possible investigation of the fate of endocrine disrupting chemicals;
- assessment of odour levels;
- assessment of storage, handling application approaches for compost, urine and leachate;
- a survey of potential users of the materials;

- field days to demonstrate the application methods and explain the risks, control methods and benefits in order to establish long term users;
- a report on the various aspects of the trial.

Sufficient information will be gathered to quantify health risks, operational aspects and benefits of reuse.

Duration and Estimated Cost of the Overall Demonstration Project

The proposed timing for the overall demonstration project and the estimated cost for establishment, operation and reporting over this period are as follows:

Approximate Timing	Stage	Expenditure
2004 to mid or late 2005	Design, approvals, marketing and construction of the apartments.	$265 000
Mid to late 2005	Establish contracts for maintenance and transport.	$30 000
Mid 2005 to mid 2006	Establishment of the agricultural reuse area and planning for the reuse trial.	$100 000
Mid 2005 to early 2006	Occupation of apartments.	–
Late 2005 to mid 2008	Operation, monitoring and maintenance at apartments	$85 000
Mid 2006 to late 2008	Execution of agricultural reuse trial.	$200 000
Late 2008	Report on demonstration project outcomes.	$50 000
2004 – 2008	**Demonstration Project**	**$730 000**

Overall, it is suggested that other parties, including, potentially, the Smart Water Fund should fund the following:

- all costs associated with transport and the proposed agricultural trial,
- all monitoring and project management and reporting costs.
- 50% of the design and supervision costs of the composting toilet installation.
- 75% of the difference between the cost of composting toilets (including associated heating and ventilation) and conventional sewerage,
- 100% of the cost of monitoring and automatic control equipment since it is provided for the purposes of investigation.

This would leave the developer (and ultimately the owner) to meet around 50% of the difference between composting toilets and conventional sanitation. None of the costs associated with extra monitoring, controls, trial facilities, maintenance and transport set up and operation would be borne by the developer. In all it is suggested that funding should be split between the developer (and in future the apartment purchasers) at no more than $230 000 (less any subsidy) and funding of research and development to benefit the wider community of $500 000 plus any subsidy agreed to make the apartments more attractive.

Policy and Regulations Relevant to the Demonstration Project and Barriers to Overcome

Composting toilets and waterless urinals have been installed in a relatively large number of public amenities, private houses and institutional buildings in Australia and there is an Australian Standard covering their design. Thus there are no particular policy or regulatory barriers to installation of composting toilets. The proposed apartment site is in the area of City West Water and negotiation on headworks charges and sewerage rates will be necessary. No particular barriers have been identified, and several councils and water authorities in Victoria have now approved or are considering applications for composting toilets within sewered areas.

Planning and building approval will be required and compliance with the Australian Standard should be sufficient to gain approval.

Composting toilets are generally associated with on-site disposal of waste, and the approval of on-site disposal of residues is the most challenging area. For this demonstration project, the reuse site will be distant from the apartments and will require EPA approval. It is anticipated that this approval will be obtained in the form of a Research, Development & Demonstration Approval.

The transport of the residue materials will not require special approvals. The status of urine, leachate and compost in terms of its waste classification and reuse in Victoria is not entirely clear. None of the residues fall under the Prescribed Waste Regulations and therefore transport can be by any means. General provisions of the Health and Environment Protection Acts will apply and it is likely that works approval would be required for any storage depot, particularly if further processing is involved.

The residues will probably be subjected to requirements for biosolids for which the EPA draft guidelines were released in November 2002. These guidelines are still in a draft stage and whilst they cover composted sewage sludge they do not cover the residues from composting toilets. Therefore there may be some scope for a subset of guidelines for compost and urine. This will need investigation during the demonstration program. Nevertheless, the biosolids guidelines do provide a framework for beneficial use of the residues.

The State Environment Protection Policy (Waters of Victoria) requires that premises be connected to sewer when they are located within a sewered area unless all wastes can be contained on site. This provision did not contemplate a composting toilet approach with off-site disposal of residues. However, such disposal regularly occurs with septage and with portable toilet facilities so no particular barrier is foreseen, other than clarification.

In summary, whilst some current policy and regulation did not anticipate large-scale transport of compost and urine to agricultural land, there are no particular barriers foreseen for establishment of the demonstration project. However, widespread application of the technology has significant implications and it is certain that new policy, regulation and guidelines will be and will need to be established before widespread use of composting toilets and widespread application of residues to agricultural land could be established.

The project has not looked at the implications of food-standards regulations on use of crops fertilised with residues. This would need review during the demonstration project.

Attitude of Regulators

Representatives of regulators and approvals bodies consulted (EPA, Human Services, Moonee Valley Council, City West Water) have indicated support for the demonstration project and it is reasonable to conclude that approvals bodies and regulators are interested in and will support for the demonstration project subject to it complying with statutory requirements.

Financial and Economic Evaluation of Large-Scale Application of Dry Composting Toilets and Residue Reuse

Financial evaluation and economic evaluations of two larger scale applications of dry composting toilets with urine separation and a grey water sewerage system have been undertaken, to a small fringe area or isolated town and to a new high density urban subdivision. These evaluations show that dry composting toilets and grey water sewerage, whilst somewhat more costly to the household to install (of the order of $2 500 to perhaps $3 000 depending on the configuration, additional building works and ventilation and heating systems), can provide sanitation at a similar overall cost to current conventional sewerage. It is likely that capital cost disadvantage would decrease with mass production of composting units and changed building design.

Several scenarios have been investigated for each type of development and conclusions drawn from these scenarios are:

- in the case where a sewerage system requires a significant capital upgrade to cater for a new subdivision where conventional sewerage is proposed, composting toilets with grey water sewerage offer a potentially less costly option, around $1 200 or 5.5% less per household in overall capital cost of the system (the house installation part of the overall capital cost would still be more costly than water-flush toilets) than conventional sewerage, the all-up cost per household of which is estimated as around $21 800;
- a similar conclusion holds in outlying areas distant from a sewer and treatment plant of adequate capacity such as many backlog areas where composting toilets with grey water sewerage have a clear financial advantage over conventional sewerage;
- where no upgrade of the sewerage system is required then composting toilets are will be about 8% more costly overall (by about $1 500/household over conventional sewerage which is estimated as $19 000/household) but are considered a more environmentally beneficial approach to sanitation;
- annual overall operating costs for a composting toilet/grey water sewerage system are likely to be of the order of $90 or 55% more per household than for conventional sewerage in a large urban subdivision but possibly $100 or 45% less than conventional sewerage for a backlog area or outlying town;
- the relative cost of energy does not have a significant impact on the relative cost advantages of conventional sewerage and composting toilets with grey water sewerage because energy costs are not a major factor in either system;
- increasing water costs in future could make composting toilets with grey water sewerage a less costly option than conventional sewerage.

The overall conclusion from the financial and economic evaluations undertaken is that composting toilets with a modified grey water sewerage system offers a potentially competitive option to conventional sewerage although, as for some other technologies that reduce environmental impact, capital cost is likely to be higher overall than for current approaches (but not in all cases).

Handling of Grey Water

This feasibility study has been based on providing a modified conventional sewerage system for grey water since, at high population density as proposed for this demonstration project, grey water cannot be sustainably used on site or on nearby parkland, particularly in winter. For a small low density town or low density suburb, dry composting toilets with urine separation and on-site grey water treatment is likely to be consistently less costly than conventional sewerage but sustainability will depend on population density. If density is more than around 20 persons per hectare then a grey water sewerage scheme will be essential in order to avoid significant long-term ground or surface water pollution by nutrients and possibly by salts. At population densities under around 20 persons/ha then sustainable reuse of grey water within the urban area may be possible but, without winter storage, it would be unwise to adopt such a scheme without careful assessment of long-term impacts.

Water Saving Potential of Dry Composting Toilets

Dry composting toilets do not use any water, therefore about 19% of an average household water usage (around 18 kL/c.yr saved out of 96 kL/c.yr currently used by the average Melbourne household) and 28% of domestic sewage discharge would be avoided by eliminating toilet flushing.

It is estimated that the long term vision of 20% adoption of composting toilets could lower overall urban water consumption in Melbourne by around 2.5% based on overall average water consumption for Melbourne of about 150 kL/c.yr (which includes non-domestic use not accounted for in the average household use of 96 L/c.yr above). For the 12 apartment trial this translates to an annual saving of 490 kL. .

The potential of composting toilets to reduce sewage flow and pollutant loads is quite significant.

For example, if around 20% of all houses and apartments were to adopt composting toilets in future, future wastewater flow from households in Melbourne could be reduced by around 5%. The impact on overall wastewater flow would be less, say around a 3% reduction because of non-household wastewater contributions.

The reduction in biosolids generation at sewage treatment plants and the avoidance of extension of treatment capacity would be more significant than water saving since composting toilets divert between 50% and over 80% of the sewage load. Thus a 20% adoption of composting toilets could potentially reduce pollutant loads by at least 5% and up to between 10% and 16% depending on the pollutant and the extent of non-domestic load in the treatment plant catchment. Residual sewage would be of lower salinity, which is an important advantage of composting toilets over grey water recycling for toilet flushing.

Energy Use for Composting Toilets Compared to Conventional Sewerage

The study has shown that conventional sewerage (which is not a high energy user compared to overall community energy use) may be more energy-efficient than dry composting toilet installations installed with mains-powered ventilation fans (which is the current practice in most installations).

Energy use is an important aspect and any system that uses more energy than a current system should be assessed in detail for overall benefit. Energy use will be monitored during the demonstration project.

The following table compares energy use of conventional sewerage with a composting toilet/grey water sewerage option. The range for conventional sewerage relates to whether the sewage treatment plant generates some of its own energy demand from biogas or not. The range for composting toilets results from different assumptions on supplemental heating and ventilation energy use.

Energy or Greenhouse Measure	Conventional Sewerage (WC waste and flushing water)	Composting Toilets and Grey Water Sewerage
TOTAL MJ/c.yr	248 - 540	171 - 529
Lifetime Emissions (50 years) tonnes CO_2-e kg/c.yr	1.0 – 2.1	0.7 - 2.1

If mains-powered ventilation and supplementary heating is necessary (the high end of the range for composting toilets) to make the composting process and installation work effectively, composting toilet systems would use more energy than conventional sewerage with some energy generation from biogas at the sewage treatment plant. If ventilation fan energy is derived from solar power and if waste heat from the apartment or passive solar heat input is sufficient to keep the compost warm, then a sanitation system based on dry composting toilets with urine separation, trucking of residues up to 50 km (a 100 km round trip) and discharge of grey water to sewer will use less mains and non-renewable energy overall than a conventional system where the sewage treatment plant does not generate any of its own energy. This situation is typical of outlying areas with their own treatment plants.

The evaluation of energy use makes allowance for embodied energy in fertiliser saved by use of compost and urine on land.

Potential Fertiliser Replacement

The nutrients in urine and compost from composting toilets could replace a proportion of chemical fertilisers used in Australia. However, even if the entire Australian population converted to composting toilets, the residues produced would still only supply about 5% of current average Australian usage of fertilisers used to supply N, P and K to the soil. This small percentage reflects the extent of our export industry for agricultural products. Overseas studies on recycling of excreta have shown that fertiliser demand to grow food for a population come close to being met by the excreta from that population.

This substitution of chemical fertiliser is an important factor in relation to sustainability, especially when comparing composting toilet residues with sewage treatment biosolids. Biosolids from sewage treatment plants in Melbourne contain little of the nitrogen, phosphorus and potassium originally present in the sewage because these nutrients are either driven off by treatment or remain in the effluent discharged to the sea or inland waters.

Health Issues and Risk Management

Health risks associated with composting toilets are considered to be no higher for householders than conventional water-flush toilets, provided insect breeding is controlled and the systems are properly operated and maintained.

For transport workers, the risk is probably less than for sewerage system workers as the materials they may come into contact with are contained and already stabilised.

Health risk to agricultural workers using residues is probably no higher than risks to current sewage treatment plant workers but it is recognised that there will be a perceived and potential health risk associated with reuse of urine, leachate and compost.

Risk to consumers of crops grown using residues should be no higher than if sewage biosolids are used and some quantitative risk assessment in Europe has shown that risk levels are negligible provide urine and leachate is stored for at least six months before use and provided solids are properly composted. If, as is likely, the residues are used on dry-land grain crops or pasture health risk to consumers is negligible.

Technical, Financial and Health Risk Management for the Demonstration Project

The demonstration project cost estimates allow for comprehensive instruction to occupiers on correct use of composting toilets, contract maintenance and residue removal to simplify responsibilities of the body corporate, intensive monitoring of health risks and for backup and standby facilities should problems arise. Risks have been listed and assessed for likelihood and management actions have been identified to minimise risks. Because similar installations are already operating, it is certain that the demonstration project is technically feasible. Contingency allowances have been included in all cost estimates and allowance has been made for conversion of the apartments to conventional sanitation at any stage of the project. If the residue reuse trial proves problematic or too costly, the residues could readily be disposed of as for septic tank waste as the quantity (12 tonne/yr) is small. Thus technical, health and financial risks can be adequately managed.

Summary

In summary, the feasibility study has shown that dry composting toilets:

- have the potential to be either of similar cost or less costly than conventional sewerage for residential accommodation of varying densities;
- are likely to be more economical than conventional sewerage as the relative cost of water rises;
- have the potential to be more energy efficient overall;
- can provide up to 19% savings in domestic water use (18 kL/c.yr) and a up to 28% reduction in household sewage discharge volume;
- can reduce pollutant loads from a household by 25% for BOD, 55% for salts and over 80% for nutrients and in the process make nutrients available for agricultural use, reduce biosolids generation and reduce discharges to receiving waters.

By saving water, recovering nutrients, removing other pollutants from wastewater and reducing waste loads to receiving waters, dry composting toilets could reduce the impact of cities on the environment.

There is increasing application of composting toilets and urine separation in Australia and overseas. A demonstration project, as proposed, would help to prove the apparent advantages and, if successful, encourage uptake of this potentially more ecologically sustainable approach to management of excreta in the urban environment, thereby contributing toward societal change for a sustainable future

By demonstrating the technology in a medium to high-density development, the technology will be subjected to the most rigorous test.

For the full version of the *Composting Toilet Demonstration Project – Feasibility Study* Report, related information and contact details for project partners refer to the project website at:

www.ghd.com.au/compostloo