

ENVIRONMENT DESIGN GUIDE

URINE-SEPARATION AND DRY COMPOSTING TOILET TRIAL – AGRICULTURAL USE OF RESIDUES

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This paper and its companion paper summarise reports published by the consulting firm GHD in 2003 and 2009, and in particular they summarise the final results of a two year trial of six urine-separating dry composting toilets and two waterless urinals, at a new secondary school in Victoria. This paper reports on an agricultural trial in which the collected urine was used as fertiliser. This trial indicated that application of urine to a growing crop of canola and growing pasture in spring is feasible. The results were insufficient to conclude that the urine is clearly as effective as conventional fertilisers, but did indicate no detriment to the crop or pasture, and similar performance to chemical fertiliser application. The project in general is discussed in the companion paper CAS 55A: Urine-Separation and Dry Composting Toilet Trial – Demonstration in a Secondary School.

Keywords:

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



Figure 1 Urine-fertilised canola plot just prior to harvest

(Source GHD, 2009)

1.0 INTRODUCTION

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

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

2.0 ANALYSIS OF RESIDUES

2.1 Urine Analysis and Characteristics

The typical analysis of urine produced during the trial is set out in Appendix 1, together with typical published data. Most components were present at concentrations similar to published data but nitrogen and phosphorus were on the low end of the range, and potassium on the high end. The collected urine is dark brown in colour and has a strong, sharp and unpleasant ammonia-amine odour. Leachate was more dilute than urine and varied greatly between samples as a result of varying addition of water to the compost. No blockages were experienced in urine pipework and build-up of scale was limited to the bases of the composters. Others have experienced blockage of 32 mm composter drain pipes when not using urine separating pedestals and some clearing of pipework may well be necessary in future at Maryborough.

The successful trial use of urine and leachate on agricultural land is detailed in Appendix 3.

2.2 Compost Analysis

A typical analysis of the compost collected is included in Appendix 2. Despite the low usage and low quantity of faecal matter and toilet paper, the concentrations of nitrogen (N), phosphorus (P) and potassium (K) in the compost samples were similar to published concentrations.

The bacteriological results indicate that, in compost that had been isolated from new additions for 36 days, there was insufficient desiccation and/or composting to reduce *E. coli* to below the EPA biosolids guideline of 100 organisms/g dry matter. *E. coli* is used as an indicator because large numbers are present in faecal matter. The composter under the male toilets running at ambient conditions produced lower *E. coli* (319 org/g dry matter) than the second composter in the female toilets (>39 000 orgs/g dry matter) which was controlled to close to 20°C. This suggests that keeping a composter warm in the absence of any temperature elevation by composting increases survival of *E. coli*. Normally, storage time without new additions would be months, not days.

3.0 AGRICULTURAL TRIAL

Low usage of the toilets meant that there was insufficient compost material for any meaningful agricultural use and that urine and leachate quantities were insufficient for use until September 2008. The objective of the urine/leachate agricultural application was to demonstrate feasibility and potential benefits on dry land pasture and a dry land crop by comparison to chemical and no fertiliser application.

A farmer willing to receive the urine and leachate was identified, preliminary soil tests were carried out and trial plots were laid out on a growing canola (oil seed) crop and on perennial pasture. Three plots, each around 100 m², were laid out on each area. This area was determined based on the mass of nitrogen in the volume of urine and leachate available. The applied loadings of nitrogen, phosphorus and potassium on the urine/leachate plots were 51 kg/ha of nitrogen, 4.9 kg/ha of phosphorus and 36 kg/ha of potassium. Similar rates were applied to chemically fertilised plots using single superphosphate, potassium chloride and urea. The rates were set to match typical nitrogen application to crops during spring of around 50 kg/ha. The urine/leachate mixture was sprayed onto the plots and then a similar volume of water was sprayed to wash residue from the leaves. The chemically fertilised plots were similarly sprayed with water to wash fertiliser from the plants. There was noticeable odour during spraying downwind but this soon subsided.

Crop response measurements in November 2008 showed there was a statistically significant higher seed count on the canola plot fertilised with urine/leachate compared to the chemical and control plots. However, low rainfall during the trial, around 25 mm, limited overall crop growth. The only conclusion that can be reliably drawn from the trial is that the canola plants on the urine/leachate plot were not detrimentally impacted by the application, and may have shown some improved yield compared to the chemical and control plots. Conclusions for the pasture plot were similar. The materials were easily collected, transported and applied.

3.1 Soil Testing and Impacts on the Agricultural Plots

Soil testing was carried out before and after the application to indicate any effects of urine/leachate and chemical fertilisers on the canola and pasture plots. There was no observed detrimental impact on soil fertilised with urine and leachate. There was a greater increase in sodium and chloride in the urine/leachate fertilised plots than in other plots. The calculated Sodium Absorption Ratios (SAR) in the applied liquids are approximately 20 for leachate and 120 for urine. A SAR value over 7 is regarded as undesirable for irrigation. However, urine and leachate were applied as liquid fertilisers, not as irrigation water so the impact of the high sodium is uncertain. It is relevant to note that the mass loading of sodium that would be applied if urine is used to supply 500 kg nitrogen/ha.yr, which is 10 fold higher than in this trial, would typically be less than the mass of sodium that would be applied in normal irrigation practice. This suggests that the sodium issue could be managed. However, long-term application, testing and observation would be necessary to confirm sodium, chloride and salinity generally would not present problems.

Estimation of the accumulation of toxic metals in the top 100 mm of soil after 100 years of urine application, indicates accumulations around two orders of magnitude lower than in relevant guidelines for soil contamination and metal concentrations in urine are far, far lower than guidelines for unrestricted biosolids application. This useful and firm conclusion suggests that sampling of urine for metals on an ongoing basis in any agricultural use scheme is unnecessary.

3.2 Value of Nutrients in Urine and Compost

At the peak of the commercial fertiliser price cycle in December 2008, the value of nutrients in urine totalled around \$20/tonne and the value in compost (assuming 28 per cent moisture in the compost) totalled around \$160/tonne wet basis. However by April 2009, these values had dropped to around \$13/tonne and \$110/tonne wet basis respectively. Organic matter in the compost would increase the value of this material. The majority of the nutrients available in excreta are in the urine (see Appendix 1) so use of this material has most potential. Increasing fertiliser prices in future coupled with economies in a large collection system could make use of urine and compost attractive in future.

4.0 CONCLUSIONS

The agricultural trial was only partly successful in that insufficient compost was available to use it as a fertiliser and soil conditioner, and the quantities of urine only allowed on application to relatively small areas of farm land. However, this agricultural trial represents perhaps the first such practical trial in Australia, and was sufficient to allow the following specific conclusions to be reached:

Urine is an effective fertiliser – Urine can easily and effectively be used as an agricultural fertiliser and, properly managed, its use could be both economical and save energy with a low risk of nuisance, health impact or detriment to soil.

Urine is low in metal content and metal accumulation in soil can be discounted as a problem – The metal content of urine is sufficiently low to ensure that, even at high application rates, there will be no detrimental accumulation in soil. Further study of this issue is considered to be unnecessary.

Salt and in particular sodium in urine may have some impact on soil over time that requires management – The sodium content in urine is high but application of urine should not add more sodium than is typically applied during irrigation. The impact of the sodium and other salts in the urine needs further investigation but long-term application to land should be manageable.

ACKNOWLEDGEMENTS

This paper includes information from a paper published in the proceedings of the World Sustainable Buildings 2008 Conference in Melbourne, Australia.

www.sb08.org

Rogers, B, Crockett, J, Soulsby, M, 2008, 'Results of a Trial Of Urine-Separation and Dry Composting Toilets in a Secondary School', *Proceedings of the 2008 World Sustainable Building Conference*, Volume 2, ASN Events, Melbourne

REFERENCE

GHD, June 2009, Smart Water Fund, Maryborough Education Centre - Ecological Benefits of Excreta Segregation, Urine-Separating Dry Composting Toilet Project, Milestone 6 Report, can be downloaded from GHD's website using the following link: www.ghd.com/global/projects/composting-toilets

BIOGRAPHY

Elise Daniels is a civil engineer who joined GHD in Melbourne after completing a combined civil engineering and arts degree at the University of Melbourne in 2007. Since then, she has gained experience in the design of water and wastewater civil infrastructure, particularly wastewater treatment plant design, as well as the provision of construction phase services. She has a continuing interest in innovative on-site and decentralised sanitation systems.

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Briony Rogers joined GHD in Melbourne as a graduate civil engineer in 2006 after completing a combined engineering and science degree at Monash University. She has been involved in a variety of water and wastewater projects during her time at GHD, building experience in the design of water and sanitation systems, management of multi-disciplinary design teams and provision of construction phase services. Briony has spent the last year working for GHD in Vietnam to gain exposure to water and wastewater engineering in a developing country context.

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Jonathan Crockett recently retired as a consulting engineer with GHD after working for 37 years in the water industry and latterly as an Environmental Auditor. He qualified as a chemical engineer from the University of Melbourne in 1971 and then completed a MEngSci in biochemical engineering. His work has included water and wastewater treatment plant design, sewerage system planning, industrial wastewater minimisation and treatment, environmental impact assessment as well as contaminated land and industrial facility auditing. His current main interest is in alternatives to conventional sanitation.

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APPENDIX 1 – AVAILABLE ANALYSES OF URINE

Analyte	Units	Typical Urine Composition at Maryborough	Literature Data (GHD 2003, 2009)
pH		6.9 - 7.8	6.2 - 8.2
Specific Gravity		1.017	
Calcium	mg/L	23-36	30-390
Magnesium	mg/L	0-23	20-20
Sodium	mg/L	2 845	570-2500
Potassium	mg/L	2 430	480-3300
Bicarbonate Alkalinity as CaCO ₃	mg/L	2 043	
Chloride	mg/L	5 102	5 000
Sulphate	mg/L	1 704	1 000
Total Solids (Evaporation at 105°C)	mg/L	24 879	
Suspended Solids	mg/L	891	
Total Dissolved Solids (105°C)	mg/L	23 457	
Organic Total Solids	mg/L	11 686	
Total Nitrogen as N	mg/L	4 613	2 000- 9 000
Total Phosphorus as P	mg/L	342	700-830
Total Copper	mg/L	0.571	0.01-0.04
Total Cadmium	mg/L	0.00	0.0001 - 0.012
Total Iron	mg/L	6.9	<0.025
Total Manganese	mg/L	0.14	<0.025
Mercury	mg/L	0.0001	0.004
Total Zinc	mg/L	0.36	0.082-0.74
Other metals	mg/L	0.008 - 0.2	
Faecal Streptococci	per 100 mL	31 000	105 to 107
Total Viable Aerobic Count	per mL	1 300 000	
E. coli MPN	per 100 mL	<100	<1 000
Faecal Coliforms	per 100 mL	>20 000	
Total Coliforms	per 100 mL	>20 000	

APPENDIX 2 – ANALYSIS OF COMPOST

Analyte	Average Analysis at Maryborough
Calculated moisture prior to wetting/homogenising	28%w/w
Total solids (Evaporation at 105°C) prior to wetting	72%w/w
Moisture as received	71%w/w RB (Recd. Basis)
Total Solids (Evaporation at 105°C)	29%w/w RB
Fixed Total Solids	19%w/w DB (Dry Basis)
Organic Total Solids	81%w/w DB
Total Kjeldahl Nitrogen as N	25 333 mg/kg DB
Ammonia Nitrogen as N	5 367 mg/kg DB
Water Soluble Nitrite Nitrogen as N	<1 mg/kg DB
Water Soluble Nitrate Nitrogen as N	<10 mg/kg DB
Total Oxidised Nitrogen as N	<11 mg/kg DB
Total Nitrogen as N	25 333 mg/kg DB
Total Potassium as K	19 333 mg/kg DB
Total Phosphorus as P	16 733 mg/kg DB
Total Viable Aerobic Count (30°C, 3 days)	570 000 000 per g RB
Total Coliforms MPN	>11 000 per g RB
E. coli MPN	66 per g RB
E. coli MPN (EPA Biosolids Guideline is 100 per/g DM)	223 per g DM
Faecal Coliforms MPN	92 per g RB

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