UNIVERSITY OF TECHNOLOGY SYDNEY

INSTITUTE FOR SUSTAINABLE FUTURES

TRANSITIONING TO SUSTAINABLE SANITATION

A TRANSDISCIPLINARY PILOT PROJECT OF URINE DIVERSION

2013

ABOUT THE CONTRIBUTORS

This research project was initiated and delivered by the Institute for Sustainable Futures (ISF) at the University of Technology, Sydney (UTS). ISF's mission is to create change toward sustainable futures that protect and enhance the environment, human well-being and social equity. For further information visit www.isf.uts.edu.au

Core research team: Cynthia Mitchell, Dena Fam, Kumi Abeysuriya (ISF)

Research partner organisations and collaborators:

AKA the Plumber: David Nixon

Caroma – GWA Group Ltd: Luke Di Michiel

City of Sydney: Nick Midlam

Lend Lease: Nick Storey

Linkoping University (Sweden): Jan-Olof Drangert

NSW Department of Fair Trading: Les Barnard

NSW Department of Health: Kaye Power

Nursery and Garden Industry Australia: Anthony Kachenko

Sydney Water Corporation: Nicola Nelson, Therese Smart, Victoria Burston, Mark Angles

University of New South Wales: Janice Gray (Law)

University of Technology, Sydney: Jennifer Williams (Design), Prasanthi Hagare (Engineering & IT), Dana Cordell (ISF), Shankar Sankaran (Built Environment), Eric Liyanage (Facilities Management), David Murphy (Facilities Management)

University of Western Sydney: Abby Mellick Lopes (Communication Arts), William Bellotti (Natural Sciences)

Yarra Valley Water: Francis Pamminger

CITATION

Cite this report as:

Cynthia Mitchell, Dena Fam & Kumi Abeysuriya 2013. *Transitioning to sustainable sanitation: a transdisciplinary pilot project of urine diversion*. Institute for Sustainable Futures, University of Technology Sydney. http://www.isf.uts.edu.au/publications/Mitchelletal2013funny-dunny-pilot.pdf

ACKNOWLEDGEMENTS

This research was funded by a Challenge Grant from the University of Technology, Sydney, a scheme intended to promote collaborative research amongst UTS researchers through new cross-disciplinary partnerships to foster multidisciplinary research for the purpose of increasing innovation and practical outcomes.

Significant co-funding (cash and in-kind) was provided by the UTS Facilities Management Unit, Sydney Water Corporation, Caroma (GWA Group Ltd), Nursery and Garden Industry Australia and Yarra Valley Water. Generous contributions of time and expertise from members of our research team, and extended peer networks are also gratefully acknowledged.

Last but not least, we are most grateful to our project participants, the users of the urine diverting toilets from the Institute for Sustainable Futures and the Australian Centre for Excellence in Local Government, for their enthusiasm and constructive feedback that has contributed enormously to the learning outcomes of the project.

INSTITUTE FOR SUSTAINABLE FUTURES
University of Technology, Sydney
PO Box 123
Broadway, NSW, 2007
www.isf.edu.au

TABLE OF CONTENTS

LEAD INVESTIGATOR'S FOREWORD

Our goal with the UTS Sustainable Sanitation project was to open up the space for urine diversion to become a viable concept in the urban environment. We knew the enormous potential value of learning by doing, and we also knew that value could only be realized if we paid great attention to the process – we needed to design a project and a process that would engage the hearts, minds, and hands of a very diverse range of partners.

We took an action research approach because we knew that the real value lay in collaborative learning along the way, losing our cultural fear of failure, and instead, fessing up to not knowing everything we needed to know up front. We knew that we would, and in fact, we thought that we should, 'skin our knees' along the way. Our view was that a university environment was the perfect place for such experiments on a broad scale, because it can accommodate the unexpected things we figured would happen. We wanted to find out what we did not know, and what we and others needed to know, to support a transition that enables urine diversion in appropriate urban settings. A significant side goal was that we wanted to demonstrate to our partners the value of an emergent approach to research – one where the overarching goal is clear, but the details of the design and the methodology are flexible enough to respond to insights that are revealed along the way.

We took a transdisciplinary approach because we needed to engage with social (toileting is an intensely private business), technical, cultural, representational, regulatory, and economic issues, and we needed to be able to work with them in both isolated and integrated ways.

From the perspective of creating change towards sustainable futures, which is our mission at ISF, this project had many drivers. Those of us who live in urban centres can do so only because our food is produced elsewhere. With massive and ongoing increases in urban populations across the world, and a growing recognition that we need to reduce our resource footprints, there is an increasingly urgent need for another revolution in our food systems, of the same scale as the revolution afforded by the advent of industrial fertilisers and pesticides, but working instead from a set of principles based on finding a better balance between social, economic, and environmental benefits and costs. Urine is an amazing resource from a food production standpoint. But it adds only problems when it is combined with other materials in our sewage systems – removing urine's nutrients before sewage is discharged or recycled has a significant energy penalty. Most of the pharmaceuticals we imbibe partition into our urine, and most of our treatment processes do not affect these chemicals, so inhabitants of aquatic ecosystems receive noticeable doses of anti-depressants, hormones, etc. We now also know that our mineral phosphate rock reserves are reaching their limits, and peak phosphorus will occur within the next few decades, so we need to find other sources of P(ee). Helping our sewage systems to transition to sustainability is therefore a core piece in the food system puzzle.

I want to acknowledge all those who made this project and its wonderful outcomes possible. Firstly, our partners: UTS Research and Innovation Office, UTS Facilities Management Unit, Sydney Water Corporation, Caroma (GWA), Yarra Valley Water, Nursery and Garden Industry Australia, UTS Faculty of Design Architecture and Building,

UTS Faculty of Engineering and IT, University of Western Sydney, Lend Lease, City of Sydney, NSW Department of Health, and University of New South Wales. As part of our application for the NSW Green Globe Awards, we were asked to provide a short quote on what it would mean if we won. What follows is what I wrote a month in advance of the decision:

'Being right on the cutting edge of sustainable innovation requires not only enormous foresight but also a great deal of gumption. Our partners in this urine diversion work have displayed both in spades, and this award is a wonderful way of recognizing their commitment, legitimizing their investment, celebrating our collective achievements, and garnering support for the future.'

Secondly, our 'funny dunny[1]' toilet users: staff, students and visitors to the University of Technology Sydney's Institute for Sustainable Futures and the Centre for Local Government on Level 11 of Building 10 on the Broadway campus. Their enthusiasm and willingness to persevere in the face of not insignificant duress was a source of inspiration for us.

Finally, and most significantly, my team – I am indebted to Dr Kumi Abeysuriya and soon-to-be Dr Dena Fam. This journey of discovery was terrifically enriched by being able to share it with, and being enormously supported by, these two warm, insightful, and humour-loving reflective research practitioners.

Cynthia Mitchell
Professor of Sustainability
Institute for Sustainable Futures
February 2013

[1] Australians have a particular predilection for slang, and are particularly prolific in their slang terms for all aspects of toileting: 'dunny' is one of many Australian idioms for 'toilet'. Australians also have a predilection for rhyming slang, which only reinforces our fondness for the term 'funny dunny' – our informal name for this project – where funny retains both its meanings: funny ha-ha and funny peculiar.

Layout of this document

	INSTALLATION OF THE UD SYSTEM	PEOPLE AND PRACTICES	VISUAL COMMUNICATIONS	AGRICULTURAL TRIAL	ANALYTICAL STUDIES OF URINE	REGULATIONS/INSTITUTIONS	FACILITATING SOCIO-TECHNICAL CHANGE	MEDIA & AWARDS	LEARNING AND DEVELOPMENT OUTCOMES
TECHNOLOGY	X	X	X	X	X	X	X		X
VISUAL COMMUNICATION	X	X	X					X	X
STAKEHOLDER ENGAGEMENT	X	X	X				X	X	
REGULATIONS/INSTITUTIONS	X			X	X	X			X
INTEGRATION	X	X	X	X	X	X	X	X	X

'I've got a real taste of how hard won a trans-disciplinary disposition is. You can't really get there unless you are involved in a project like this, confronting difficult issues and working through them. That's actually how you shift your own perspective into a more trans-disciplinary mode. You have to…fall over, fail and make mistakes in order to achieve a broader, more empathetic perspective'.

Dr Abby Lopes, School of Humanities and Communication Arts, University Western Sydney

The research was conducted through teams allocated to each of five research strands described in Chapter 2 "*What did we do*" – namely Technology, Visual Communication, Stakeholder Engagement, Regulations and Institutions, and Integration. The transdisciplinary nature of the research meant that there were intersections and overlaps between research strands, with many possible ways of telling the story. Since learning was the primary goal of the project, we have structured this report along the key categories of learning that emerged as the project progressed. The matrix above illustrates the relationship between the report sections/categories of learning (vertical headings) and the research strands (coloured horizontal 'strands').

Each chapter begins with this matrix to locate the particular learning within the larger context of this work. We have also chosen a quote that resonates with the chapter, from amongst the many 'gems' spoken by our large group of collaborators.

1 WHY?

Figure 1: The urine diversion toilets (Wostman and Dubbletten) trialled in the UTS Sustainable Sanitation Project

Why trial urine diversion systems?

Phosphorus (P), together with Nitrogen (N) and Potassium (K), are critical elements for plant and animal growth, and therefore food production. There is no substitute for phosphorus: it is essential for global food production. Modern commercial agriculture is dependent on chemical fertilisers (containing PNK) derived from phosphate rock. Yet phosphate rock, like oil, is a non-renewable resource with estimates suggesting that approximately 50-100 years remain of current known reserves. To make matters worse, a peak in global production – peak phosphorus – is estimated to occur by 2035 (Cordell, Drangert et al. 2009) with increasing demand for phosphorus expected in the medium to long term due to an increasing global population, preferences towards more meat- and dairy-based diets (which demand more phosphorus) in emerging economies, and increasing demand for non-food crops such as biofuel.

Alternative sources of phosphorous are needed and as we excrete 90% or more of the nutrients we consume (Cordell, Drangert & White 2009), sewage offers a potential source of phosphorus. The question is where in the sewage system does it make sense to intervene to recover nutrients? Extracting phosphorus and other nutrients that have been combined with other sewage products (including trade waste) is highly energy intensive (Wilsenach & Van Loosdrecht 2003). Urine diversion (UD) offers a way of separating nutrients and has the potential to recovery approximately 80% of nitrogen and 50% of phosphorous in domestic wastewater (Larsen et al. 2001). The primary advantage of urine diversion is that it offers a form of phosphorus directly available to plants (Jönsson et al. 2004). It could be argued that urine represents a viable source of fertiliser which could contribute to global food security with modelling suggesting that approximately 20%-50% of agricultural fertilisers could be sourced from human urine (Drangert 1998; Cordell, Drangert et al. 2009).

There are many other significant benefits associated with UD. For example, wastewater treatment that removes nutrients from sewage has the potential to significantly reduce energy use at treatment plants (Wilsenach and Van Loosdrecht 2003). In addition nutrient recovery and reuse of urine keeps nutrients out of waterways. Many persistent organics and pharmaceuticals are discharged into urine (Larsen et al. 2001), so these too are kept out of aquatic systems, reducing the environmental impact of sewage. Urine reuse also displaces the environmental impacts associated with fertiliser production.

Where has UD been installed?

Broad landscape drivers such as water scarcity and nutrient and energy constraints have triggered a number of international water authorities to undertake UD pilot projects, including the German Technical Corporation (Blume 2008), the Dutch Foundation of Applied Water Research (Wilsenach and Loosdrecht 2001) and the Swiss Institute of Aquatic Sciences and Technology (Larsen & Lienert 2007). More recently, in Australia, three UD pilot projects have been initiated in quite different circumstances: in a Queensland eco-village initiated by a private developer (Hood 2008); in a Victorian peri-urban community initiated by the water authority Yarra Valley Water (MacDonald and Narangala 2008) and this project, in a higher education institution initiated by the Institute for Sustainable Futures at the University of Technology Sydney in NSW (Abeysuriya, Fam et al. 2010).

Why was it important to trial UD at UTS?

The decision to install the UD trial within the urban institutional setting of the university was deliberate. Three characteristics distinguished this project from others: population density, building type, and value orientation. In short, if urine volume is what we want then we have to work out how to engage with densely populated, urban locations such as the one selected for the UTS trial, as opposed to the peri-urban location of other trials both locally and internationally. The institutional setting provides a different building typology, with public rather than private toilets. It also provides many layers of complexity in the stakeholders involved, from users, through commercial cleaners to facility management professionals, including service personnel such as tradespeople and designers. Finally, the users we set out to engage with (the diverse population of a city university) likely represent a broad swathe of values, practices, and preferences, in comparison with the motivations of ecological communities using UD.

The UTS trial aimed to investigate and illuminate the range of barriers to the uptake of UD systems. The inherent inflexibility of the dominant paradigm of centralised sanitation creates significant barriers for the diffusion of alternative options. In many industrialised countries centralised sanitation systems are the well-intentioned product of more than a century of capital infrastructure investment, institutional structures and embedded social habits of practice which present significant challenges to the introduction of alternative more sustainable sanitation options. The difficulty in deliberately changing the existing system toward a more sustainable one is the fact that a transition from one system to another requires not only the introduction of new technologies but also new markets, user practices, regulations, institutions, infrastructures and cultural meanings. This suggests that change cannot be brought about through technological innovation alone but rather requires institutional and socio-cultural transformations to occur as well (Geels, 2006).

While Australian pilot projects in Queensland and Victoria focused on investigating the technological and social issues associated with trialling UD, the UTS trial took a transdisciplinary approach to actively consider how a very broad suite of issues (including stakeholder engagement, regulations and institutions, technology, visual communications) were implicated in the process of system change. This required engaging with users, industry, government and academic partners in a reflective process of action research.

References

Abeysuriya, K., Fam, D., Hagare, P. & Williams, J. 2010, 'Transitioning to sustainable sanitation through cross disciplinary, practice-based research: an on-campus pilot of urine diversion at UTS', paper presented to the *The 10th international conference of Australasian campuses towards sustainability (ACTS Inc): connecting curriculum and campus*, Melbourne, Australia.

Blume, S. 2008, 'Two years of experiences from a urine diversion project in GTZ Headquarters, Eschborn, Germany', paper presented to the *IWA World Congress and Exhibition*, Vienna, Austria, 9th September, 2008.

Cordell, D., Drangert, J.-O. & White, S. 2009, 'The Story of Phosphorus: Global food security and food for thought', *Global Environmental Change*, vol. 19, no. May 2009, pp. pp.292-305.

Drangert, J.-O. 1998, 'Fighting the urine blindness to provide more sanitation options', *Water SA*, vol. 24, no. 2.

Geels, F.W. 2006. The hygienic transition from cesspools to sewer systems (1840-1930) : The dynamics of regime transformation. *Research Policy,* 35**,** 1069-1082.

Hood, B. 2008, 'Domestic urine separation is effective in capturing plant macronutrients, nitrogen, phosphorus and potassium', paper presented to the *On-site and decentralised sewage and recycling conference - Coming clean: sustainable backyards and beyond*, Benalla performing arts and convention centre, Victoria, Australia, 12-15th October, 2008.

Jönsson, H, Stintzing, A, Vinnerås, B, & Salomon, E 2004, Guidelines on the use of urine and faeces in crop production, EcoSanRes Programme and the Stockholm Environment Institute, viewed 23 January 2011

Larsen, T. A., Peters, I., Alder, A. , Eggen, R., Maurer, M. and Muncke, J. 2001, 'Reengineering the toilet for sustainable wastewater management', *Environmental Science and Technology*, vol 35, no. 9, pp 192A-197A.

Larsen, T.A. & Lienert, J. 2007, *NoMix – A new approach to urban water management. Novaquatis final report*. Swiss Federal Institute for Environmental Science and Technology (Eawag), 8600 Dübendorf, Switzerland

MacDonald, S. & Narangala, R. 2008, 'Decentralised or centralised and how to choose?', paper presented to the *On-site and decentralised sewerage and recycling conference*, Benalla, Victoria, Australia, 12-15th October, 2008.

Wilsenach, J. & Loosdrecht, M.V. 2001, *Separate urine collection and treatment: Options for sustainable wastewater systems and mineral recovery*, STOWA, Utrecht.

Wilsenach, J. & M. Van Loosdrecht 2003, 'Impact of separate urine collection on wastewater treatment systems', *Water Science and Technology*, vol. 48, no. 1, pp. 103–10.

2 WHAT DID WE DO?

The UTS Sustainable Sanitation Project had an exploratory intent to pilot urine diversion, recovery and reuse systems within the institutional setting of the university campus to reveal the range of interdependent factors that determine successful uptake and potential scale-up of radical sustainable urban sanitation. The university provided an ideal protected space for trialling sociotechnical innovation for the purpose of learning. The university could be seen as a microcosm of society, in which the risk of innovation for industry or community stakeholders should be able to be absorbed as research enterprise (Allen, Lopes & Andrews, 2009).

Transdisciplinarity was the overarching research frame for the UTS trial, informed by an action research methodology (Dick 2004). Together, these provided a flexible and learning-focused approach to the project. Three cycles of action research were designed over three phases of the project: (1) investigation; (2) design, contract and commission; and (3) operate, monitor, evaluate and decommission. Four distinct strands of research were created to address the key dimensions while a fifth research strand had the role of integrating the other strands with a whole-of-systems perspective (see Figure 2).

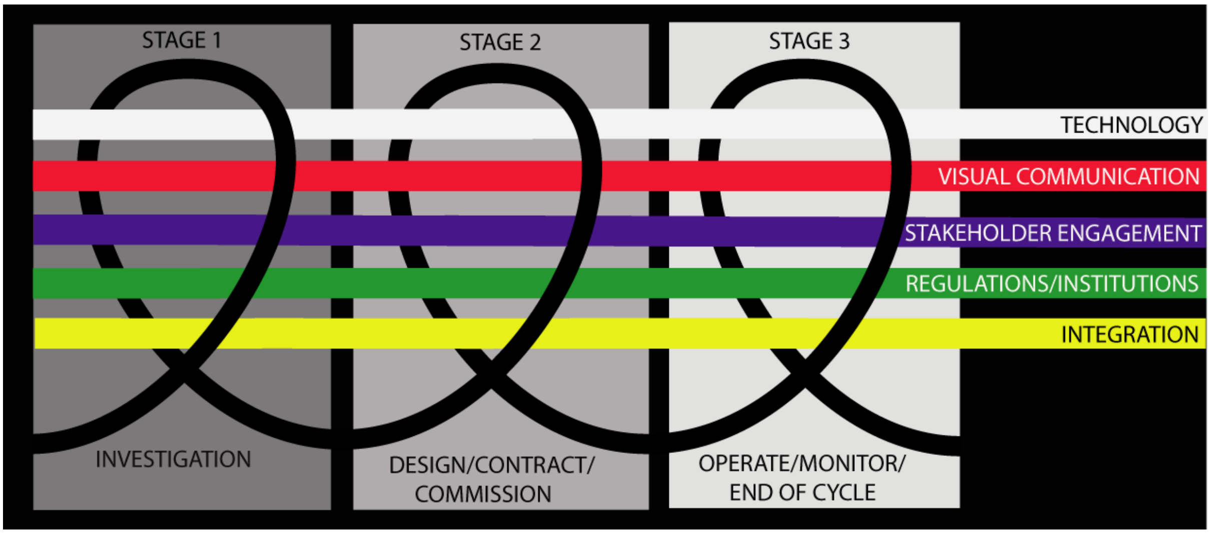


Figure 2: Schematic of the plan for five strands of research spanning three action research cycles

Our research approach was also guided by Transition Management (TM), a field that offers strategies to consider broader possibilities for innovation beyond incremental improvements to dominant existing designs. TM is a deliberate attempt to bring about structural change in socio-technical regimes (Kemp et al, 2007) with an emphasis on involving key stakeholders '…to define multiple visions of the future…and realise important collectively defined goals' (Meadowcroft 2009, p. 325). Our initial meeting therefore devoted significant time to a visioning exercise where team members positioned themselves in the future, at the completion of the project, and imagined the conversations they were having at an event to celebrate the project's completion. Intriguingly, some significant aspects of these visions that seemed incredibly far-fetched at the time did manifest over the course of the project (see also chapter on *Facilitating socio-technical* *change*). Perhaps the best example of this was our project leader's vision of a leading developer announcing their commitment to installing urine diversion toilets in a significant high-profile commercial development. This was so unimaginable in the short time-frame of the project that it got a good laugh from the team, which at that point did not include developers. However, by the end of the project, Lend Lease had committed to urine diversion pipework in Barangaroo, the last large water-front development in downtown Sydney, and UTS had committed to urine diversion pipework in their next new building.

While we had clear and cogent plans on how we wanted our cycles of research to operate, we also set out with the recognition that we may well 'skin our knees' because there were many, many unknowns. In other words, we were prepared for unexpected and emergent learnings to influence the direction of the project. So, in reality the project ran very differently from our plan (See Figure 3). Early in our project, an opportunity arose to conduct a local pilot with a UD toilet model chosen by the water utility Yarra Valley Water working on a parallel but separate UD trial. We took this opportunity and discovered, to our surprise, this technology (reputedly the most popular UD system on the Swedish market) did not function as specified or as expected (see chapter on *Installation of the UD system*). This experience led us to scale down the size of the UD toilet trial from 10-15 units in an uncontrolled on-campus setting to a total of 4 UD toilets in a more controlled public setting with stronger user engagement and feedback (see chapters on *Installation of the UD system* and *People and practices* for more detail). This was complemented by a separate UD collection and storage trial based on the more mature technology of waterless urinals, this time accompanied by usage monitoring (the mind boggles, doesn't it? You'll have to read on to find out). Samples of urine were used in agricultural trials and chemically analysed. In downsizing the scale of the trial, visual communication strategies also changed from design interventions that initially sought to engage a large cohort of university students to a more intimate approach of engaging a smaller sample of participants in sharing their perspectives in the trial (See Chapter on *Visual communications).*

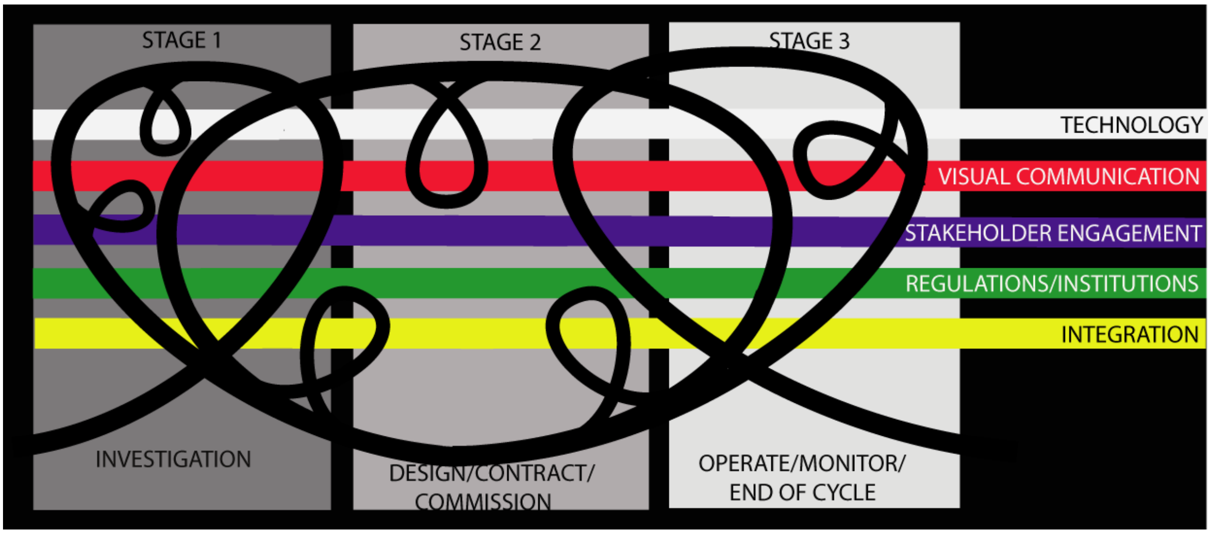


Figure 3: Schematic of what really happened!

Who was involved?

A diverse group of researchers, staff, and key industry and government stakeholders were strategically identified and invited to engage in the UTS Sustainable Sanitation project to provide transdisciplinary perspectives and expertise. The project drew together 15 collaborators across five faculties, three industry sectors, two State government agencies and one local government entity (see Table 1). The research team was led by academics from the Institute for Sustainable Futures (ISF) at UTS and included other academics from UTS as well as the University of Western Sydney (UWS) and University of NSW (UNSW) in an inter-university collaboration that brought research strengths in Sustainable Futures, Engineering, Project Management, Visual Communication, Law and Agriculture. Key industry and government stakeholders were also involved, including Sydney Water Corporation, toilet products manufacturer Caroma Dorf (GWA Group Ltd), the industry group Nursery & Garden Industry Australia, NSW Department of Health, NSW plumbing and drainage regulator Office of Fair Trading, and the local government authority City of Sydney. The UTS Facilities Management Unit was a central partner, with their staff and contractors providing diverse input to and feedback on the trial from the perspectives of public toilet operation and management in a university setting, cleaning services, occupational health and safety, plumbing retrofits, and building management sustainability in both design and operation.

The project was funded by the UTS Research and Innovation Office under the university's Challenge Grant Scheme along with financial contributions from our industry partners including, Sydney Water, Caroma Dorf, and Nursery Garden Industry Australia.

As well as engaging key industry, government and academic stakeholders, we purposefully created opportunities for students at multiple stages of their training to be involved in the project. This included undergraduate and postgraduate students, and early career researchers, who had opportunities to be involved in practice-based research (See chapter on *Learning and development outcomes* for further information)

Table 1: Collaborators involved in the UTS project across academia, industry and government

ACADEMIA	INDUSTRY	GOVERNMENT
Law (UNSW)	Toilet manufacturer	Local Council
Agriculture (UWS)	Nursery and Garden Industry Association	Plumbing and Drainage regulator
Design (UWS &UTS)	Water utility	Department of Health
Engineering (UTS)		
Transdisciplinary research (ISF)		
Systems thinking (UTS)		

Transdisciplinary (TD) approach

The intent of the UTS trial was to investigate the complex and multi-dimensional issues associated with introducing UD systems in practice. This required investigating not only the viability of the technological system but also the social and regulatory system and the interface and overlap between these systems. The complex, messy, and ambiguous issues associated with installing UD in practice could not be adequately tackled from a single disciplinary perspective, therefore the UTS trial aimed to move beyond disciplinary boundaries of inquiry. The trial was problem focused with the intention of creating change in the context of the trial. Adopting a 'problem focus' rather than a disciplinary focus meant there was no single methodology associated with UTS trial, but rather reflection on and response to the problem being investigated. This led to an evolving methodology over the timeframe of the trial.

Toileting is an intensely personal experience, so we wanted to take a strongly socio-technical approach i.e., we set out to engage with both the social and the technical, and to do so from an experiential viewpoint. That meant we sought social knowledge and expertise of the problem from the full breadth of actors involved with public toileting in an institutional setting, including government, industry and academic actors as well as the community involved in using and managing the UD system (i.e., users, cleaners, plumbers and maintenance personnel). Transdisciplinary inquiry in the UTS trial involved five overlapping strands of research, including:

Technology: the contribution of the technology strand was in the plumbing and engineering inputs in designing, installing, operating and maintaining the hardware (toilets and plumbing); urine sampling, collection & storage systems; treatment/sanitising systems; transport systems; and agricultural systems. In addition the technology strand analysed the urine for its microbial and nutrient content.

Stakeholder Engagement: This strand's contribution focused on engaging with the primary participants impacted by the trial (maintenance staff, plumbers and toilet users) to determine what needed to change for the system to be more widely accepted. This included identifying pre-conceptions of UD systems by all those involved (actual toilet users e.g., UTS staff, students and visitors; as well as cleaners, tradespeople, building managers, facility managers, research managers), determining arising issues and managing these from both a research and practice standpoint, from developing resources on cleaning UD toilets through to meeting local risk management protocols.

Visual communication: The visual communications strand contributed tools to facilitate user engagement. Students from design schools at two universities developed visual prototypes to introduce the concept of 'Peak Phosphorous' and closed loop cycles of nutrient recovery. These prototypes used systems diagrams, animations and interactive design tools. Other outputs from this strand of research included environmental graphics, information graphics, feedback tools, logos and web design for the project (See chapter on *Visual Communications* for details).

Regulations & Institutions: The regulatory strand's contribution was to investigate regulatory enablers for and impediments to resource recovery and reuse of urine in agriculture. This strand of research identified and reviewed the regulatory frameworks triggered by installing UD systems, including plumbing regulations and the bulk transport of urine for reuse on agriculture. As protection of public health is important and Australian plumbing regulations are strict this strand of research made sure we had approvals in place.

Integration: The primary contribution of the integration strand was to structure the project to 'learn through failure' by embedding reflective practice into the project design and delivery. A secondary and perhaps more obvious contribution was to encourage and support interaction between strands, and conversations and relationships amongst team members, and in the process to develop collective problem definition/s and ways of improving the situation[2]. This required creating spaces that could safely contain constructive contestation, negotiation and the exploration and clarification of underlying frames of reference.

All five strands of research overlapped and/or interfaced with each other in the process of transdisciplinary inquiry. In particular the technology strand overlapped with stakeholder engagement and visual communication via the exploration of the social implications of UD through social research. The regulatory strand necessarily overlapped with the technology strand in the investigation of plumbing and transportation regulations impacting the trial. Figure 4: Transdisciplinary interaction across strands of research in the UTS project shows how the integration strand functioned as a steering mechanism across the interacting strands of research, overseeing the project, identifying impediments in the process and facilitating areas of crossover between research strands.

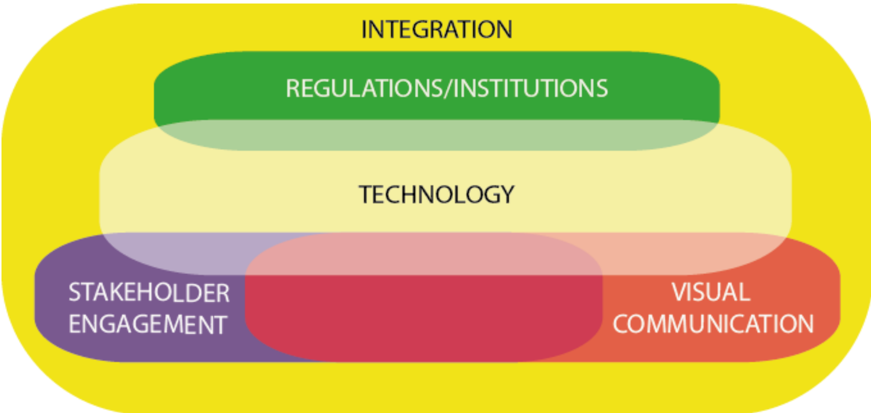


Figure 4: Transdisciplinary interaction across strands of research in the UTS project

A transdisciplinary approach to visioning a shared outlook for UD in the UTS trial

Envisaging a shared outlook for UD to identify specific research questions in the UTS trial involved combining a 'futures triangle' (Inayatullah, 2005) and STEEP analysis (Morrison, 1992). The 'futures triangle' required reflecting on the potential of UD from three perspectives; (1) in relation to the aspirations of UD (or what we all aspired to in the future for UD e.g. a close looped nutrient recovery system), (2) in relation to the pushes of UD (or the factors we can't avoid e.g. declining availability of nutrients for agricultural production) and (3) the weights of the future (or the inertia of the existing environment e.g. regulations limiting the reuse of wastewater in agriculture). To ensure broad coverage within each of these categories of drivers, the STEEP (Social, Technological, Economic, Environmental and Political) framework was incorporated into the visioning process (See Figure 5 for representation of the visioning process).

[2] When addressing what systems thinkers technically define as a 'mess' (Armson 2011), i.e. a problem situation with a great deal of complexity, interconnectedness, and high stakes, the first step is to let go of the notion of a single solution, and rather to seek ways and means of arriving at an improvement in the situation.

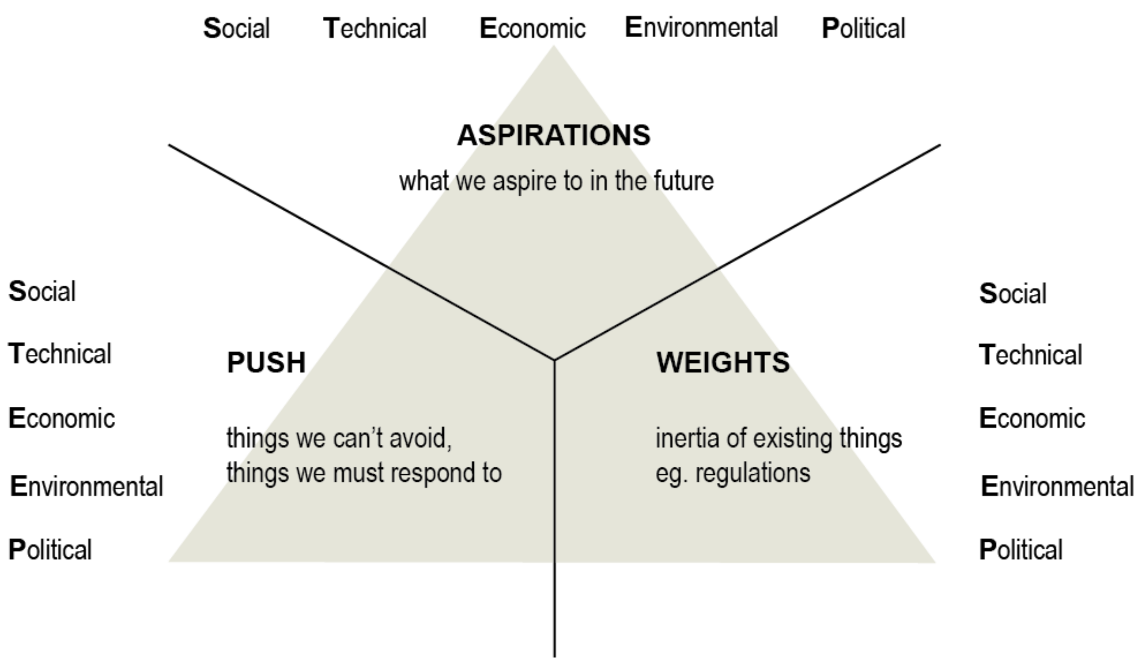


Figure 5: Template for visioning the future of UD within the UTS project team using a combined Futures triangle and STEEP analysis

Through the visioning process individual team members contributed their perspectives of a plausible future for UD and in the process translated these outcomes into relevant research questions based on their own expertise and professional interests. Table 2 provides an example of the outcomes from the visioning process in the UTS trial.

The development of research questions in the UTS trial involved all team members in the project contributing to the identification of social, technological, economic, environmental and political (STEEP analysis) factors associated with 'aspirations', 'pushes' and 'weights' of a future UD system (Futures triangle) regardless of disciplinary perspectives. Transdisciplinary perspectives were sought with input from engineers into social issues associated with trialling UD and vice versa, social scientists providing input into the technological design of the trial. In this way disciplinary perspectives were shared and learning across disciplines facilitated.

Table 2: Outcomes of the visioning process in the UTS trial

	ASPIRATIONS **(Things we aspire to in the future)**	**PUSHES** **(things we can't avoid and have to respond to)**	**WEIGHTS** **(Things that create inertia in the system)**	***RESEARCH QUESTIONS***	**HOW WERE THE RESEARCH QUESTIONS ANSWERED?**
Social	A social climate where UD and the reuse of urine in agriculture is acceptable	Lack of knowledge about 'Peak Phosphorous'	Cultural taboo in regard to the practice of toileting	*How do we engage the UTS community in ownership of the project and participation in the trial of UD systems?*	The visual communication strand and two design schools developed a range of systems diagrams, feedback tools and information packs for users of the UD systems
Technical	Successful retrofit and expansion of the scale of the UD experiment	First generation technical issues of UD toilets	Inappropriate infrastructure for retrofitting existing buildings with UD	*What kinds of operational issues need to be considered in retrofitting UTS buildings with UD?*	Industry partners conducted Australian standards testing of UDTs, stakeholder engagement strand conducted social research on functionality of UDTs with end-users, cleaners and plumbers
Environment	Understanding of the environmental impacts of reusing urine in agriculture	Declining phosphate rock resources	Phosphorus seen as a pollutant	*What is the value of human urine as a source of plant nutrients with regard to phosphorus and the management of electrical conductivity?*	Pot trials were conducted with industry and academic partners to compare urine uptake in plants in comparison to conventional fertilisers
Economic	The establishment of a viable market for local uptake of urine as a nutrient source	Volatile fertiliser prices	No incentives	N/A	(Team members did not have the time, expertise or motivation to explore this field of inquiry)
Political	Supportive institutional arrangements that make UD feasible	Lack of good precedents in the regulatory frameworks to support urine transport/reuse	Society is overly wary of the health risks associated with the reuse of sewage	*How do existing regulatory requirements impact the development of the project and what would supportive regulatory arrangements look like?*	Government and academic partners explored existing policies that support and/or hinder transportation of urine and identified potential policy areas in need of law reform

REFERENCES

Allen, J., Lopes, A., & Andrews, T. (2009, November). Futures West: A design research initiative promoting sustainable futures for western Sydney. Paper presented at Cumulus 38º South: Hemispheric shifts across learning, teaching and research Melbourne, 12-14th November

Armson, Rosalind 2011. Growing Wings on the Way: Systems Thinking for Messy Situations. Triarchy Press. ISBN 978-1-908009-36-4.

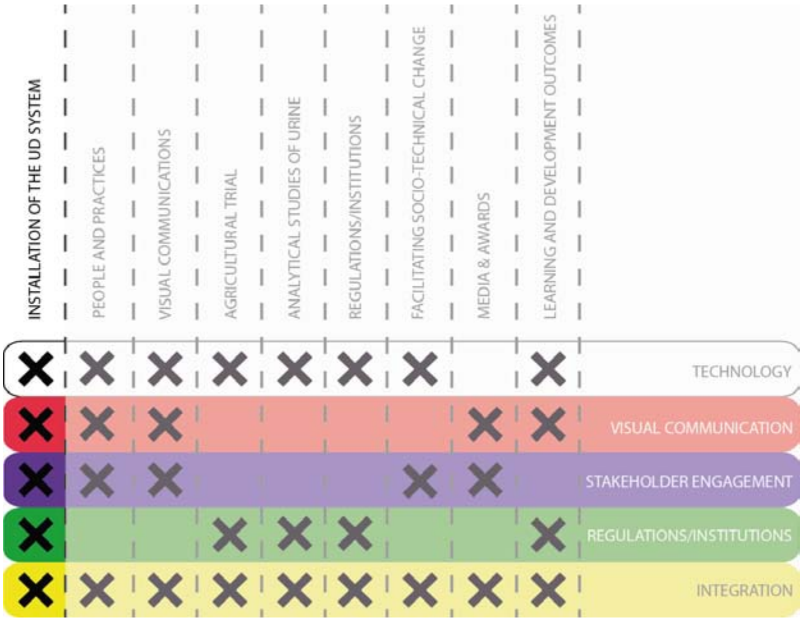
Inayatullah, S. 2005. Questioning the future: Tools and methods for organizational and societal transformation, Tamsui, Taipei, Tamkang University.

Kemp, R., Loorbach, D. & Rotmans, J. 2007, 'Transition management as a model for managing processes of co-evolution towards sustainable development', *International Journal of Sustainable Development and World Ecology*, vol. 14, pp. 78-91.

Meadowcroft, J. 2009, 'What about the politics? Sustainable development, transition management and long term energy transitions', *Policy Sciences*, vol. 42, pp. 323-340

Morrison, J.L. 1992. Environmental scanning. In: Whitely, M.A., Porter, J.D. & Fenske, R.H. (eds.) A primer for new institutional researchers. Tallahassee, Florida: The Association of Institutional Research.

3 INSTALLATION OF THE URINE DIVERSION SYSTEM



'I'd really like to be able to say that we understand how these systems would work, what the role is because if there's going to be more of these around, it's in everyone's interest that we know that they work well, are governed well and managed well, and it's all about building sustainability and developing up our sustainable options for servicing with water and waste water and anything that contributes to that is positive'

Dr Nicola Nelson, Sydney Water Corporation

The project intended trialling a full suite of technological elements with potential to capture and reuse urine at scale. The team's plan was to retrofit a male and female toilet block at the UTS city campus with 5-7 urine diverting toilets each (leaving several standard toilets in place to allow users a choice) and waterless urinals; to collect the urine in moveable tanks located in a vehicle-accessible space; and have the tanks transported to the UWS agricultural campus for use in field trials. We planned to trial several different models of urine diverting toilets[3] and waterless urinals, and to track user perceptions so we could compare devices and identify preferred characteristics.

The Action Research methodology allowed the project to depart significantly from the original plan, when the opportunity to pilot one UD toilet model (the Swedish UDT market leader *Wostman Ecoflush*)[4] in the 'investigation' phase led the team to realise that apparent success in the Swedish residential market did not automatically translate to successful performance or positive user experiences in an Australian public context. The unexpected experience with the Wostman UDT (discussed later in this chapter) led us to realise that a much more 'protected space' was needed to trial UDTs than the on-campus toilet block serving a wider segment of university traffic. Therefore the project was redefined as a trial of two UD toilets (Wostman Ecoflush and *Dubbletten* by BB Innovation

[3] A number of different commercial models from overseas manufacturers were identified and contact was made with suppliers.

[4] The contribution of the toilets by Melbourne water utility Yarra Valley Water is gratefully acknowledged.

& Co.[5]) which were installed consecutively on the 11th floor of the campus building where the offices of the Institute for Sustainable Futures are located (UTS Building 10). The floor is shared with the Centre for Local Government, and staff from both institutes were supportive, tolerant and honest in providing feedback on their voluntary participation in the trial. The revised location also enabled very close monitoring the trial by the ISF team.

The revised UTS on-campus element of the project had two components. Firstly, on Level 11, we had UDTs discharging urine to sewer, with the aims to:
(a) track user experience and perceptions of the UDTs,
(b) capture and learn from cleaners experiences with the maintenance of UDTs, and
(c) capture and learn from the plumber's experience with the installation process including compliance with applicable plumbing regulations. The installation process is critical and complicated because UDTs have two sets of pipes – a challenge for retrofitting in existing multi-storey commercial buildings with 200mm thick concrete floors.

Secondly, two urinals (*Cube H2Zero* model by Caroma)[6] were installed at a separate on-campus location (UTS Building 1) with the aims to:
(a) track behavioural patterns in urinal use, and
(b) conduct a scaled down trial of urine collection and storage.

This chapter discusses the installed system elements represented in the upper half of Figure 6 below.

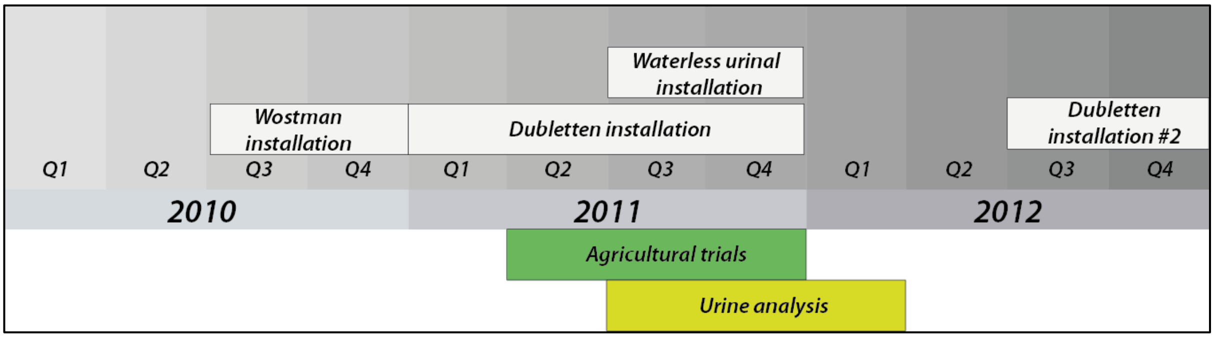


Figure 6: Timeline of the Technology research strand. Installed elements (in grey) are the focus of this chapter.

3.1 URINE DIVERTING TOILETS (UDTS)

3.1.1 Configuration of urine diverting toilet installation

One toilet of three in the female toilet block and one of two in the male toilet block was replaced by a UDT, so users had a choice whether to use a standard toilet or the UDT.

A schematic of the installation is shown in Figure 7. The urine pipework had to pass through the concrete floor to discharge to the sewer in the floor below. This arrangement

[5] The significant discount provided by Mr Bobby Bogdan Mrozowski, CEO, BB Innovation & Co, is gratefully acknowledged.

[6] The contribution of urinals and framing and installation design work from collaborating partner Caroma (GWA Group) is gratefully acknowledged.

was necessary for three reasons: to allow for sampling, to provide adequate fall in the lines to avoid struvite precipitation, and to allow for installation consistent with the manufacturer's instructions. A urine sampling device was included in the pipework of the female toilet[7]. Since the *Wostman* urine outlet is exposed with no grating or odour seal, an

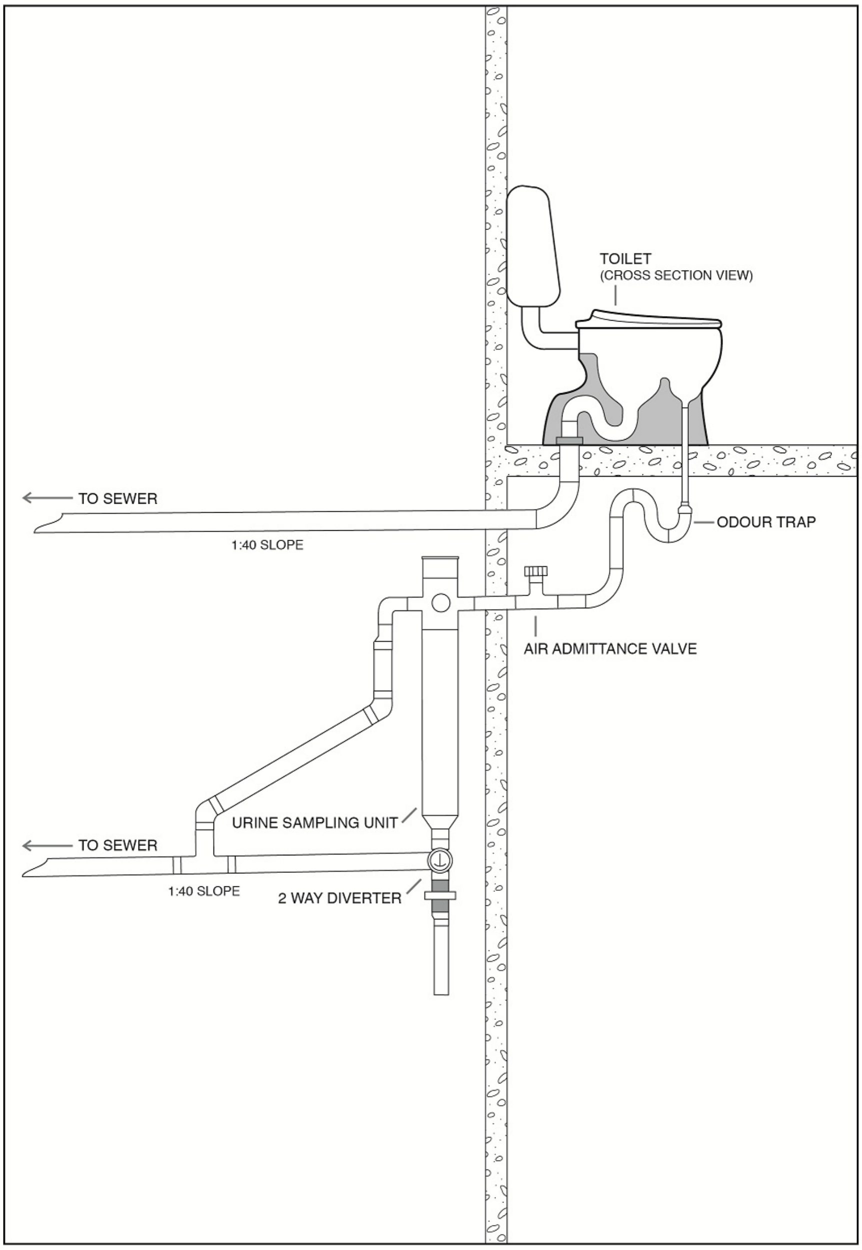


Figure 7: Schematic of UDT installation

S-bend trap was added to prevent sewer odours entering through the toilet, as recommended by the manufacturer. A water trap odour seal is also required for all

[7] The absence of a service duct cupboard below the male toilet meant it was not possible to install a similar sampling device with the male toilet.

sanitary plumbing by the State Plumbing Code of New South Wales[8]. Existing urine diversion literature also recommends an odour trap (Von Muench et al. 2009; Kvarnström et al. 2006), although specific designs are not suggested. A one way air admittance valve[9] was included to vent the pipework.

3.1.2 Performance of the UDTs

3.1.2.1 Testing against Australian Standards

Prior to installation, the performance of each UDT model was tested against manufacturers' specifications and against the Australian Standard for standard dual flush water closets (AS 1172.1-2005)[10]. The standard relates to traditional flushing toilets and does not consider the unique features of UDTs. We decided nevertheless to test the UDTs against the tests specified in this Standard, to gain some understanding of the UDTs potential operational performance in key areas (Table 3) prior to installation in the trial.

Table 3: Key results of Australian Standards performance tests

Australian Standards Test	Wostman Ecoflush UDT	Dubbletten UDT
Flush volumes measured vs. manufacturer's specifications	5.1/1.3 L were significantly higher than the 2.5/0.2 L claimed in Wostman brochures	5.4/3.4 L consistent with claims of 4L flush of rear bowl.
Paper and solids flushing[11]	✖ Failed paper half-flush test ✔ Passed paper full-flush test ✔ Passed solids full-flush test	✔ Passed paper half-flush test ✖ Failed paper full-flush test ✔ Passed solids full-flush test
Water seal minimum depth	✖ Water seal depth (25mm) failed to meet standard (45mm)[12]	✔ Water seal depth (52mm) passed

The laboratory test results raised concerns about the flushing performance of both toilets. The Wostman results were more of a concern, because the unit failed the half-flush test, which is the predominant use in practice, so we were keen to monitor flushing closely when installed in situ. Because the Wostman was the first unit installed, it was the focus of

[8] See later for conflict with water seal with our second UDT model which comes with an in-built silicone odour seal.
[9] See http://www.pic.vic.gov.au/resources/documents/1.01_Air_admittance_valves2.pdf
[10] The tests, carried out in a laboratory accredited by National Association of Testing Authorities, Australia (NATA), includes testing flush effectiveness with standardised test media representing solids and paper, water seal depth measurements, and a range of other tests - degree of splashing, liquid contamination remaining after flushing, bowl washdown, etc.
[11] Measurements against Australian Standard for Water Closets using specified test media for toilet paper and solids.
[12] Insufficient depth is especially a concern for installations in multi-storey building where negative pressures can build up in the sewer pipework and break the water seal.

many flushing questions and also provided an opportunity for pilot participants to learn successful UDT behaviours (see below for details). With the Dubbletten, the test produced a surprising and counter-intuitive flushing result, that paper test media was discharged successfully with the 3.4L flush but failed with the 5.4L flush. This result is hard to explain. There were no flushing issues in practice.

3.1.3 In situ flush performance

Post-installation performance was monitored using weekly in-cubicle surveys, mainly with the *Wostman Ecoflush* which was the first UDT installed (see chapter on *People and practices* for additional details).

In view of the results from the laboratory tests, several weeks were devoted to asking users questions about the performance of the half-flush. There were three dimensions to our investigation on the performance of the half-flush: how it was impacted by the duration of the flushing; the amount of toilet paper; and the nature of toilet paper.

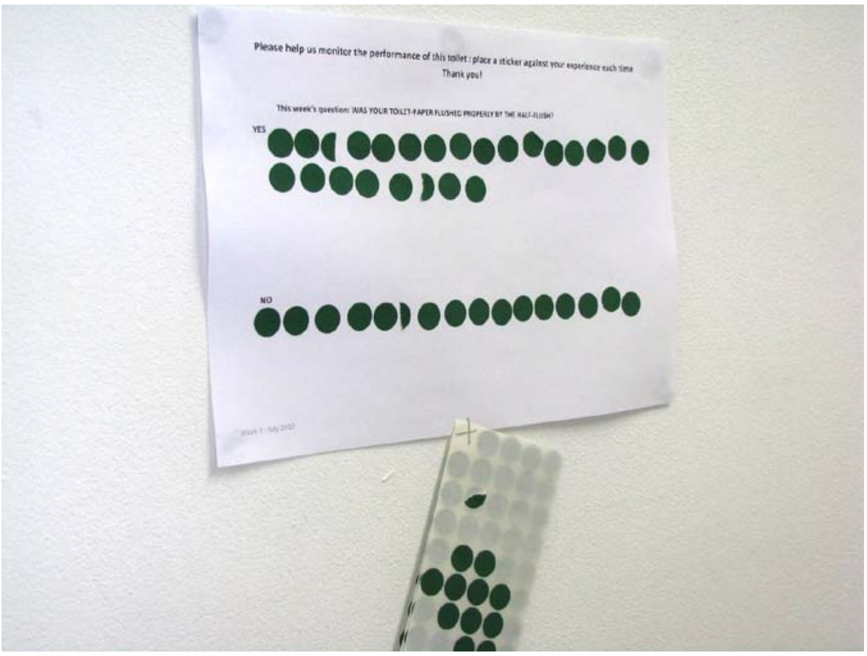
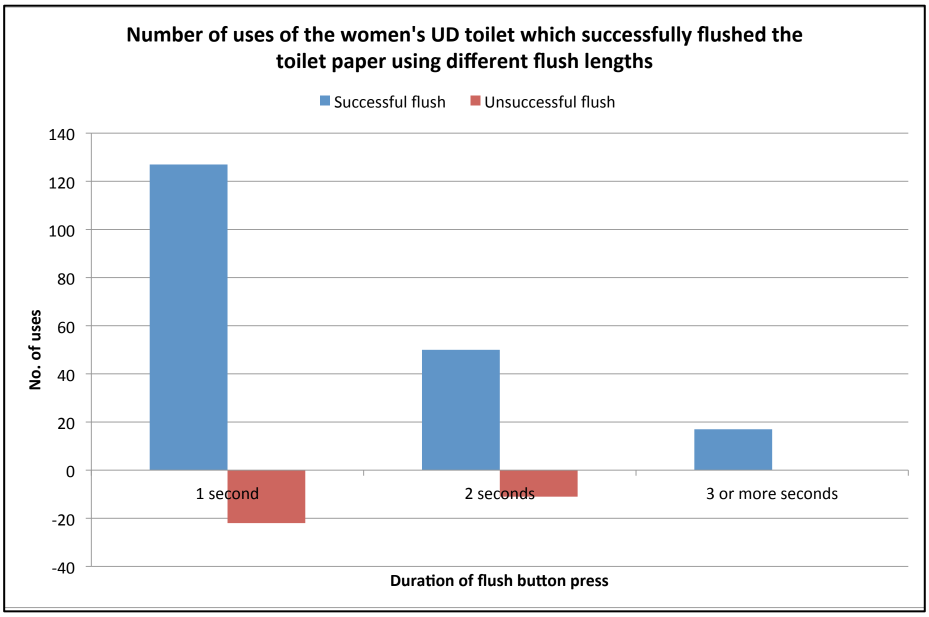


Figure 8: Example of in-cubicle survey chart

We needed to capture information from users within the toilet cubicle, while minimising risk of contamination between users before they had a chance to wash their hands. We hit on the idea of using sticky dots that users could peel off and place against preferred answers to a multiple choice question posted inside the cubicle. Each week's question would often build on learning from the previous week. For example, to explore the impact of flush duration, we asked the following questions on successive weeks:

- Was your toilet paper flushed by the half-flush?
- Was your toilet paper flushed by a long/short half-flush?
- Was your toilet paper flushed by pressing the half-flush button for 1 second? 2 seconds? 3 or more seconds?
- Was your toilet paper flushed by pressing the half-flush button for ½ second? 1 second? 2 seconds?



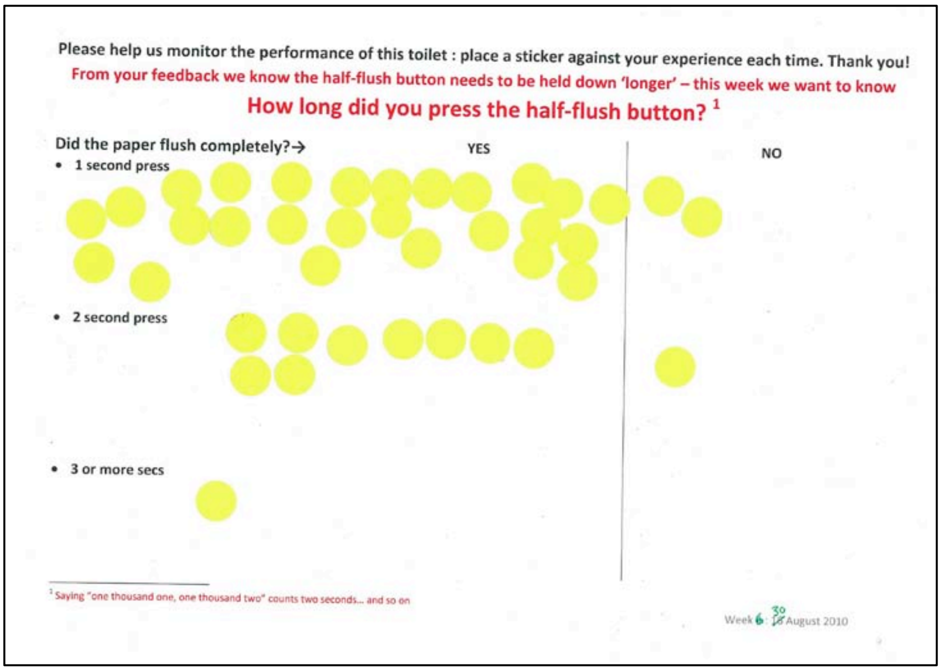


Figure 9: Sample chart used for in-cubicle survey (bottom), and graphic representation of collated data from women's toilet about the relationship between duration of flush button press and success or otherwise of toilet paper flush (top).

The dependence of performance on people's practices was highlighted by our users, who learnt very quickly how to adjust their practice for successful half-flushing: early in the first week, users answered 'no' more frequently than 'yes' to whether the paper flushed, but this trend reversed by the middle of the week. Subsequent questions indicated they learnt to hold down the half-flush button for longer (which can lead to flush volumes up to a full flush). Holding the flush down for 1 second appeared adequate on average. Monitoring of the standard toilets revealed that the flushing failure rate with the *Wostman Ecoflush* was comparable to the failure rate with a 'normal' toilet.

We investigated a few different practices that could potentially influence flush performance and found, perhaps surprisingly, that flushing effectiveness was not sensitive to the type of toilet paper (single ply, double ply and recycled etc), nor the lengths of paper most commonly used (also see chapter on *People and practices*)

3.1.4 Performance of the Wostman UDT

The *Wostman Ecoflush*, reportedly the market leader amongst UDTs in Sweden, performed poorly in two important respects: in separating urine from faeces and maintaining low dilution rates of water and urine. While end-users may have contributed to cross contamination of urine with faeces and a higher dilution rate as they became more accustom to using the systems, these key failures were primarily a result of design shortcomings that user practice could do little to mitigate.

3.1.4.1 Poor separation of urine and faecal matter

The design of the separation wall (dam) meant that the urine bowl was very easily contaminated with faecal matter [13]. We had several episodes of faecal material blocking the urine outlet. This design flaw was compounded by the lack of a grate over the urine outlet, which meant solid materials including toilet paper would very easily become lodged in the urine outlet and create a blockage. Our cleaning staff also observed that, in more public locations, such an exposed outlet would be an invitation for vandalism. A question from a student in a public lecture about what happens when people vomit into UD toilets also raised concerns about the effectiveness of the Wostman toilet.

The location of the dam made faecal marking of the dam highly likely. Flushing did not wash the dam with sufficient speed/force during a full flush so markings would persist when they occurred. Users communicated via the graffiti board (see chapter on *People and practices*) criticising the design of the toilet, while also discussing ways of changing sitting postures to reduce cross contamination and marking. Cleaning staff expressed concern about occupational health and safety issues around cleaning faecal blockages, including the need to wear a face mask when using a brush to clean off faecal material.

3.1.4.2 Dilution of urine with flushwater

The *Wostman Ecoflush* is designed so that flush water flows across the urine bowl each time the toilet is flushed, in both half and full flush mode. We measured the volumes of flush water entering urine outlet at approximately 390 ml with each half-flush[14] and 475 ml with each full flush. These volumes result in over 100% dilution of urine (i.e., over 1:1) if we assume around 250 ml as the average volume of urine discharged per use. For the collection and reuse of urine, this dilution rate is problematic. Firstly, dilute urine requires larger collection and storage tanks that can be especially difficult in commercial buildings where available space is scarce. Secondly, sanitisation of urine by storage occurs because the harsh environment created by urine causes microorganisms to die off.

---

[13] This can be less of a problem in home situations where users have chosen to install a UDT and are motivated to adapt and learn the new practices needed to avoid problems, which could explain the 'success' and market leadership of this UDT model in the Swedish niche market.

[14] Volume when half-flush was held down for 1 second. The flush water would continue as long as the half-flush button was pressed and could reach the volume from the full-flush.

Diluted urine is less harsh for microorganisms and hence less effective at sanitisation (Schonning and Stenstrom 2004). The high dilution rate associated with the *Wostman* UDT would require significantly longer storage times or other treatment for sanitisation. Thirdly, the highly dilute urine may reduce the feasibility of reuse by providing more irrigation water than required.

3.1.5 Performance of the Dubbletten UDT

The *Dubbletten* UDT was installed twice during the trial. The first installation replaced the *Wostman Ecoflush* in 2011. Our team was very surprised to discover that this toilet performed poorly with respect to discharge of urine, especially because one of our core team had been impressed by her experience using an earlier model from this manufacturer. We attributed the performance decline to the modifications that had been made to the silicone one-way valve for odour control since the previous model. The UDT was removed after nearly 11 months, at the end of this phase of the trial. This toilet was then transferred and installed at an ISF staff member's home. To our research team's surprise, the ISF staff member reported no issues with this toilet's performance. Further reflections helped us realise that the cause of the poor performance at UTS might have been with the installation rather than the design, so a second *Dubbletten* was re-installed.

3.1.5.1 Dubbletten performance during the first installation

Compared with the Wostman, the Dubbleten experience presented far fewer issues with faecal contamination of the urine bowl. Whilst the dam design was better, we suspect that the performance was enhanced by the social learning that had occurred for trial participants i.e., participants had learned how to use a UD toilet. One significant benefit of the Dubbletten toilet was the silicone odour valve and ceramic protector over the urine outlet which eliminated the problem of blockages in the urine outlet.

Figure 10: (a) The Dubbletten flushing mechanism - the white button for rinsing the urine bowl, and silver half and full flush buttons activate the flushing of the rear bowl
(b) Water jet rinsing the urine bowl

The Dubbletten toilet's design enables urine dilution by flushwater to be kept to a minimum, by providing a separate button-operated mechanism to rinse the urine bowl by a jet of water. The jet flows only as long as the button is pressed, and discharges around 80 ml of water if the button is held down for 1 second. The urine bowl generally does not need to be rinsed after each use because it drains 'clean', and the toilet paper is flushed in the rear bowl. Users commented that the act of flushing the rear bowl satisfied the habitual norm of flushing the toilet after use, without generally needing to press the extra button. So, the dilution of urine in the Dubbletten is not only much lower than the Wostman, but also may reduce to zero because the design makes urine flushing optional.

Whilst in the end the Dubbletten functioned very well, the path to arrive at that point was circuitous and full of surprises, and therefore an important learning journey. The path started when we began to experience slow drainage of urine with the first installation of the Dubbletten, taking as long as 3 minutes for the bowl to empty. This experience was surprising and fascinating, since we knew these toilets functioned well elsewhere in this regard. Such slow drainage was also an unacceptable problem for toilet users generally, although committed users continued using the *Dubbletten* by creating new user practices - for example, users would close the lid after urination as a warning to the next user of a potentially full urine bowl.

3.1.5.2 Repeat installation 2012

Figure 11 (a) Our plumber drilling the hole for the urine pipe in the 200 mm-thick concrete floor and (b) Holes drilled in the floor for the urine outlets of the Wostman and Dubbletten UDTs

Reflections and closer inspection led to the realisation that in installing the *Dubbletten* UDT, the plumber had avoided the difficult and costly task of drilling a second hole in the 200 mm thick concrete floor for the urine pipe. Even though the position of the urine collection pipes differed by about 100mm, the difficulty of the drilling the hole meant the plumber decided to re-use the hole made for the *Wostman*. This meant the Dubbleten's urine pipe did not go vertically through the floor, but rather at an angle, which required a flexible line that presented a risk of kinking. Whilst the plumber was fairly certain this would not have caused the problem, the satisfactory performance of the same toilet in our colleague's home when installed with strict adherence to the manufacturer's instructions convinced our research team that the slow urine drainage issue was due to the way it was installed. We decided to re-install the UDT with a new hole in the concrete floor.

The re-installed Dubbletten at first continued to demonstrate slow drainage, as predicted by the plumber. The team next turned its attention to another plumbing feature inherited from the Wostman installation – the S-bend odour trap. We theorised that the S-bend interfered with the pressure drop required for the performance of the toilet's silicone one-way urine valve[15]. Once the S-bend was removed, the urine drained immediately, as designed. Our enthusiastic users were just as excited as the team about this result, as the stakeholder feedback chart for that day shows.

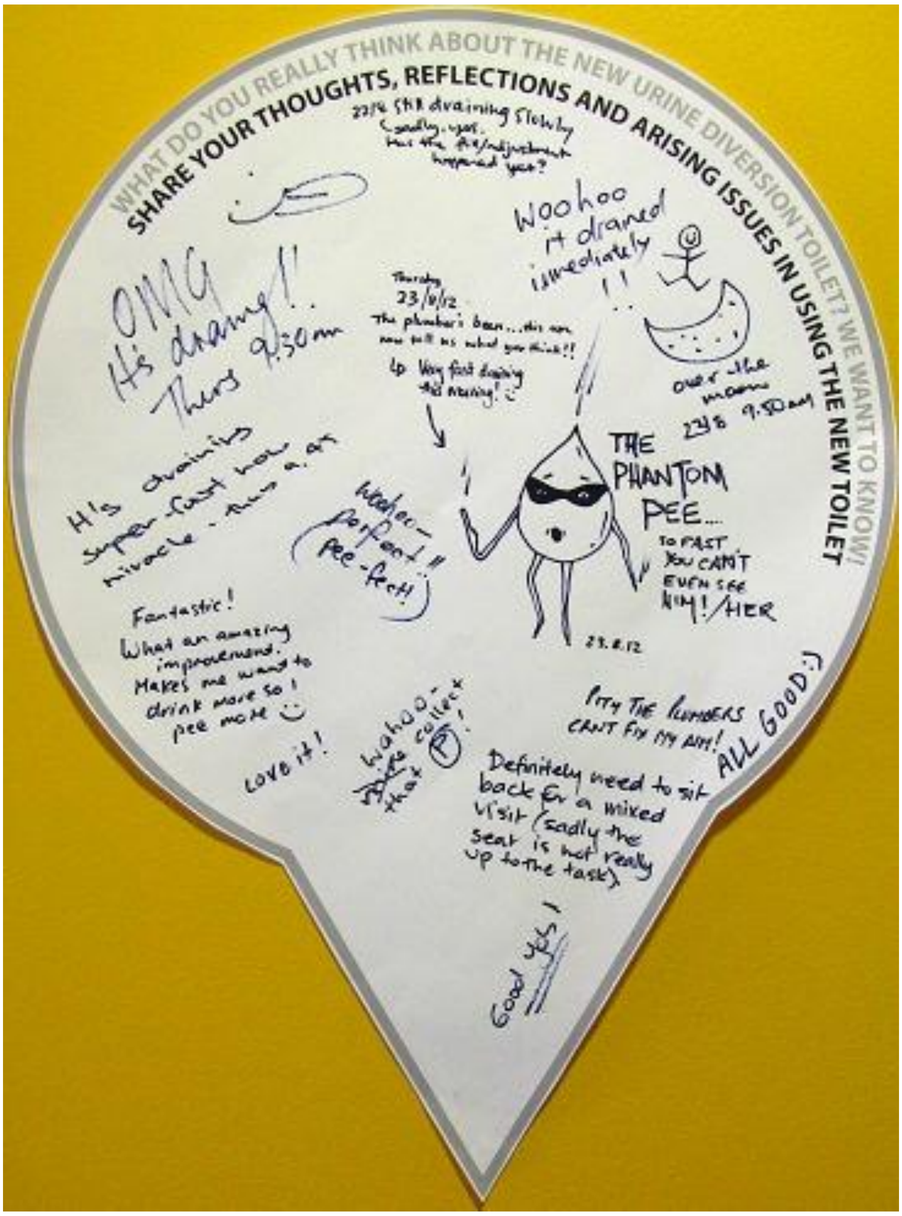


Figure 12: Stakeholder feedback chart on the week when the Dubbletten started draining was filled with delighted comments.

[15] The silicone valve is designed to open when there is a pressure exerted from the bowl side (by urine), but lock if the pressure is greater below (so sewer odours don't enter the toilet). We theorised that the liquid seal in the trap may have caused the pressure in the air column to increase slightly on entry of urine, enough to prevent the valve from opening.

The process of negotiating with our plumber to remove the odour trap was interesting in itself. Negotiations required a departure from his years of practice compliance with the Plumbing Code requiring a trap to be installed with all sanitary fixtures. His first response was to enlarge the trap, and then to simplify the trap, and finally, to assuage our relentless requests, to remove the trap altogether (see Figure 13). Although our plumber was an enthusiastic and insightful participant in the project at every turn, and contributed strongly to design discussions in team meetings, this experience highlighted that even the best plumbers need training to appreciate and apply the distinctive principles for urine pipework when they depart from conventional plumbing codes[16].

Figure 13: The plumber's series of alternative modifications to the *Dubbletten's* urine pipework that required departure from the Plumbing Code.

In addition to causing urine to back up in the Dubbletten's urine bowl, the odour trap was also identified as a highly likely culprit for the surprising level of microbial contamination observed when analysing our urine samples (see chapter on *Analytical studies of urine*).

3.2 WATERLESS URINALS

Figure 14: (a) The plumber installing metal framing to the existing slab urinal to retrofit the waterless urinals (b) The retrofitted waterless urinals.

[16] Departure from the Code can still be compliant with plumbing regulations by obtaining special approval for "performance based installation" (see chapter on *Regulations and institutions*, and *Appendix 2*).

3.2.1 Configuration of waterless urinals installation

Two *Caroma Cube H2Zero* waterless urinals were installed on the ground floor of UTS' central administration building adjoining a café, where diverse users included students, staff and visitors to the university. A schematic of the installation is shown in Figure 16 [17]. The urinals were connected to a 1000L tank situated one floor below the toilet block in the basement carpark. The tank was installed with a spill containment bund beneath it, sized to contain the full volume of liquid in the tank in line with the risk management requirements for occupational health and safety (see chapter on *Regulations and Institutions*). The tank and bund were surrounded by a locked cage to meet Occupational Health and Safety requirements as well as limit interference with the trial (Figure 15).

Figure 15: (a) The installed tank (b) The Saniflow pump and urine sampling unit

The tank was fitted with an overflow outlet connected to the sewer, to avoid spills if urine volumes exceeded the capacity of the tank. The closest accessible sewer pipe relative to the tank location was in the ceiling space above, so a pump (Sanivite by Saniflo Group) was installed to direct tank overflows back to sewer, and to empty the tank when required (Figure 15). This pump was recommended by our plumbing experts as a robust performer in similar situations, where toilet fixtures were below sewer grade. Since gravity-flow access to a sewer in retrofit situations for urine diversion can be expected to be variable, it was valuable to trial the performance of such a pump in this application. The pump was

[17] The water seal odour trap shown in the schematic was a legacy from the slab urinal that was retrofitted with the waterless urinals. The trap did not interfere with the urine drainage from the waterless urinals which use a silicone one-way valve of a different design to the Dubbletten UDT's. The trap is however a site with high risk of struvite build up that could cause blockage.

performing without fault after one year of operation[18]. The installation included a 5 litre sampling device for occasional collection of small volumes of urine for analysis.

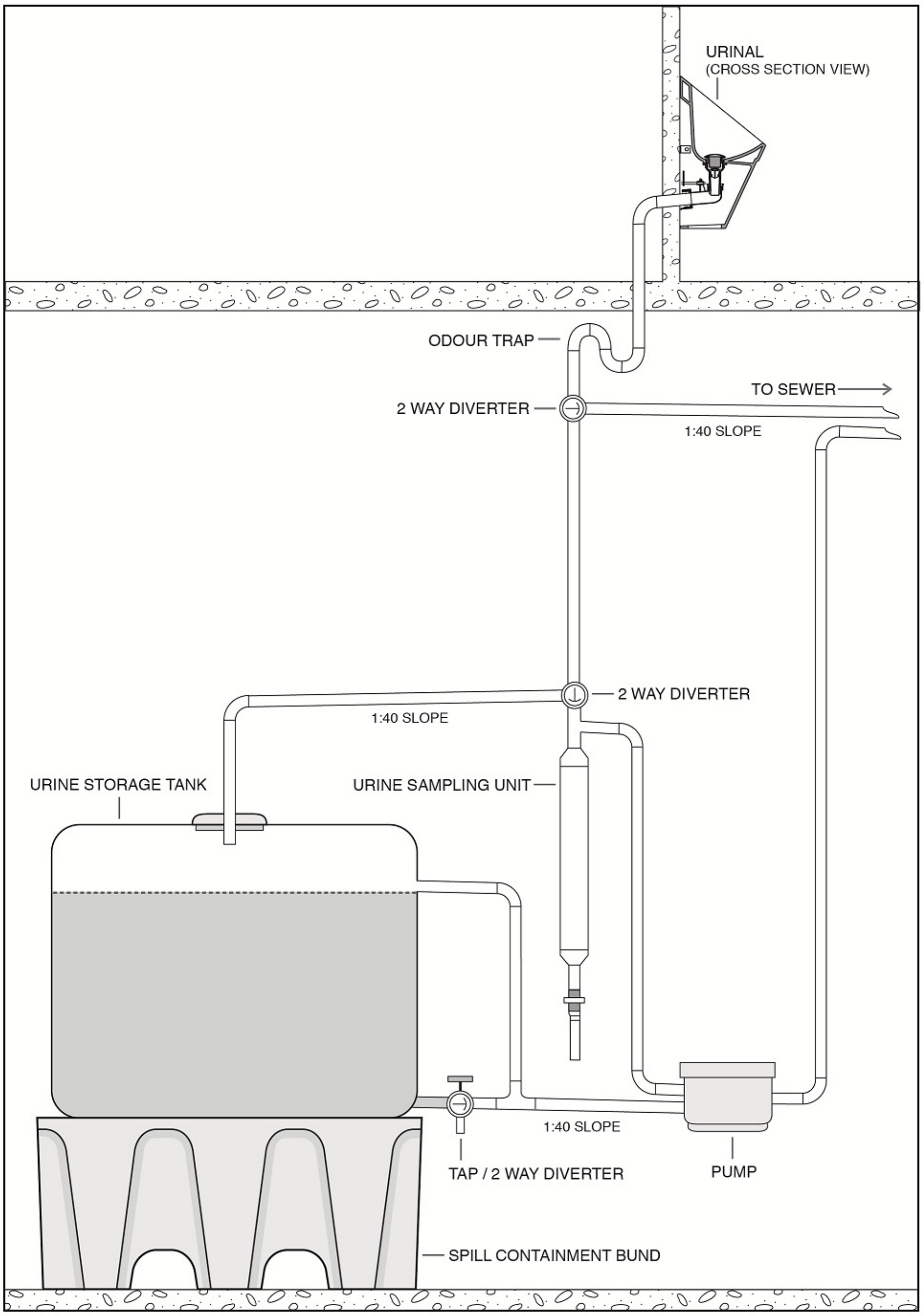


Figure 16: Schematic of waterless urinal installation

[18] Our plan was to inspect the pump at the conclusion of the trial, however with a decision to leave the urine collection hardware in place for potential follow-up research it was decided not to risk damaging the pump by dismantling it.

3.2.2 Monitoring of the Waterless Urinals

The location of the urinals was in a public place with highly variable patronage, compared with the UDT installation. Our partners from the UTS Facilities Management Unit, who have considerable experience with vandalism of university property, advised that it would be best not to alert users to the use of urinals in the UTS trial (e.g. through the use of informative signage). Since waterless urinals are a relatively mature technology there was no need to track user feedback.

Waterless urinals were monitored with electronic usage counters that were triggered by urine flow. Weekly data was collected to estimate the level of use (see chapter on *People and practices*), which was dependent on academic time frames of semester, special events held near the installation, and other external factors.

3.2.2.1 Urine volume per use

The volume of urine excreted per visit to the toilet is an important metric for sizing tanks[19]. Utilising electronic usage monitors connected to the urinals and the tank manufacturer's built in scale for measuring urine volumes collected in the tank, we estimated the volume of urine for each visit to be approximately 280 ml/visit, (see Table 4).

Table 4: Urine volume per use measurements

Dates (dd/mm 2011)	Number of uses of urinals	Volume change in urine tank (litres)	Average volume per use (millilitres)
31/08 - 05/09	454	124	273
24/10 – 02/11	1000	284	284
07/11 – 14/11	738	203	275

3.2.2.2 Urine collection and storage tank

In line with the general aims of the project, the urine tank was installed to reveal the practical issues associated with urine collection and storage. There are two possible configurations for a tank: a fixed tank with urine transferred by a tanker vehicle and discharged into storage tanks at reuse site, or a movable tank that is transferred on a flat-deck vehicle to the reuse site. We sought to investigate the latter as it was the more complex option, and would therefore provide more insights, although we did not move the tank in reality. The urine collected in the tank was not targeted for any purpose (the agricultural trial was limited to a small scale pot trial (see chapter on *Agricultural trial*), and urine analysis was performed on samples diverted before reaching the tank). Therefore we purchased a second-hand moveable tank made of heavy duty food-grade plastic, and commissioned our plumber to make easily detachable connections with the fixed pipework that would make it easy to move. This turned out to be more difficult than expected and is an area for further design research and testing.

---

[19] While some rules of thumb estimates exist for urine per person per day (Von Muench & Winker 2009), this is a less useful metric for urine collection in commercial buildings.

If we were to repeat the trial, we would design the tank/collection system to limit nitrogen (N) losses, an issue described extensively in the literature (Jönsson et al. 2004, Von Muench & Winker 2009). This involves reducing opportunities for the gases in the tank above the urine to escape. To reduce gases escaping through the pipework would require the urine inlet to be submerged, and the inlet side of the overflow to have a curved 'sleeve' that is submerged. The tank would also need to be pressure equalized (Jönsson et al. 2004, Von Muench & Winker 2009).

A possible avenue for further investigation was identified through our use of a second-hand tank that had held vegetable oil in its previous life. In the early days of using the tank, we were surprised to notice that there were no noticeable odours from the urine when the tank lid was opened[20]. A possible explanation was that the oil residues in the tank had formed an odour seal, preventing ammonia gases escaping. At the end of the trial there were unmistakable strong malodors when the tank was opened for pumping, which would be consistent with the oil having been lost over time via the overflow arrangement.

3.2.3 Maintenance of urine pipework

Figure 17: Clogged pipework found on existing flushing urinals

Issues around struvite build-up in urine pipework, whilst being a special consideration for UD systems (Kvarnström et al., 2006; Von Muench & Winker 2009), are not limited to UDTs and waterless urinals. These issues are also common with flushing urinals because of poor maintenance routines. When retrofitting the waterless urinals, we found that the pipework for the existing flushing slab urinal system was well on its way to catastrophic failure (Figure 17). It is common for users not to activate a manual flush on urinals, so flushing urinals frequently function more like waterless urinals, but without the provision of the extra maintenance required. Since urinals are installed in most male toilet blocks, this observation highlighted that failing urinal pipework is likely to be widespread across the urban non-residential buildings sector now. Counter-intuitively, struvite build-up is in fact

[20] The tank lid needed to be opened when we had to pump urine to reduce the level to enable measurements for volume per use discussed previously.

less likely to manifest with UD systems because it is a recognized risk and is managed through design and operational actions.

Urine pipework in commercial multi-storey buildings have special constraints. While Kvarnström et al. (2006) recommend pipework gradients of 1:25 to minimise struvite buildup, high-rise buildings have limitations on the possibilities for steep pipe gradients since banks of waterless urinals and/or UDTs in toilet blocks need to be connected together on each level. This research project brought together key industry stakeholders to discuss design considerations for the installation of urine diversion pipework in multi-storey buildings that led to a set of guiding principles being developed (see chapter on *Facilitating socio-technical change*, and *Appendix 1: Practical pointers for installing UDTs and waterless urinals*). This move was catalyzed by the decision by UTS to incorporate urine pipework in the new Faculty of Engineering and Information Technology (FEIT) building currently under construction, to provide a protected space for trialing UD and to provide research opportunities for further practice-based research and training in the field. The design principles for limiting struvite deposits in multi-storey buildings are based on regular (daily or weekly) flushing of the pipework, and periodic jet cleaning, in addition to increasing pipe gradients as much as possible. Given the clogging of pipework found in flushing urinals, regular flushing and jet cleaning would appear to be a good maintenance strategy for all urinal pipework, in addition to UD pipework.

In conclusion, our project indicated that current designs of UDTs and social practices in public toilets meant that UDTs may not yet be ready for installation in public spaces. Although the Dubbletten model installed at UTS continues to function satisfactorily, the unusual nature of the self-selected cohort of users leads us to be cautious about recommending UDTs in a less protected public space in the immediate future. On the other hand, they have stood the test of functioning satisfactorily in an office space, indicating that they have potential to perform well in households with a well-managed learning period to acquire new habits of practice (also see *Appendix 1: Practical pointers for installing UDTs and waterless urinals*).

Waterless urinals, as a mature technology requiring no new social practices, are ready to play a role in urine diversion in urban institutional buildings today. However there is more research needed on other parts of the urine diversion system, including urine pipework (see chapter on *Facilitating socio-technical change* and *Appendix 1*), regulations, markets, transport, reuse, etc.

ACKNOWLEDGEMENTS

We would like to thank the following individuals/organisations for their valuable contributions to the research in this chapter.

- *David Nixon*, our plumber extraordinaire, who went beyond the call of duty in cooperating with good humour and generosity with his time, and suggestions for the installations
- *Luke Di Michiel, Stephen Cummings and associates at GWA Group Ltd* (Caroma Dorf) bathroom product manufacturers)who conducted the laboratory measurements for technical data on the UD toilets; contributed the two waterless urinals and electronic usage counters, and designing and providing the metal framing for retrofitting the urinals on the existing slab urinal

- *Les Barnard of Sydney Water, representing the plumbing regulator,* for installation advice and assistance with obtaining the necessary regulatory approvals
- *David Murphy, Building Manager of UTS Building 10*, for sharing sometimes scary insights to the trials and tribulations of keeping public toilets functional in a university setting, and many hours of advice and collaboration about siting the trials
- *Prasanthi Hagare* (Faculty of Engineering and Information Technology) for her many contributions to the Technology Strand
- *Staff from the UTS Facilities Management Unit*, including Patrick Woods (DVC, Resources) for the allocation of funds to be used in hardware, installation and research; Eric Liyanage for his many contributions; Fiona Martin and Danielle McCartney of the Sustainability Office, and Mary Anne Claridge of Central Services, for their support in numerous ways
- Melinda Johnson of Swan Services, for her cooperation and active participation in team meetings, and to her staff for conveying feedback through her about UDT cleaning and maintenance.

REFERENCES

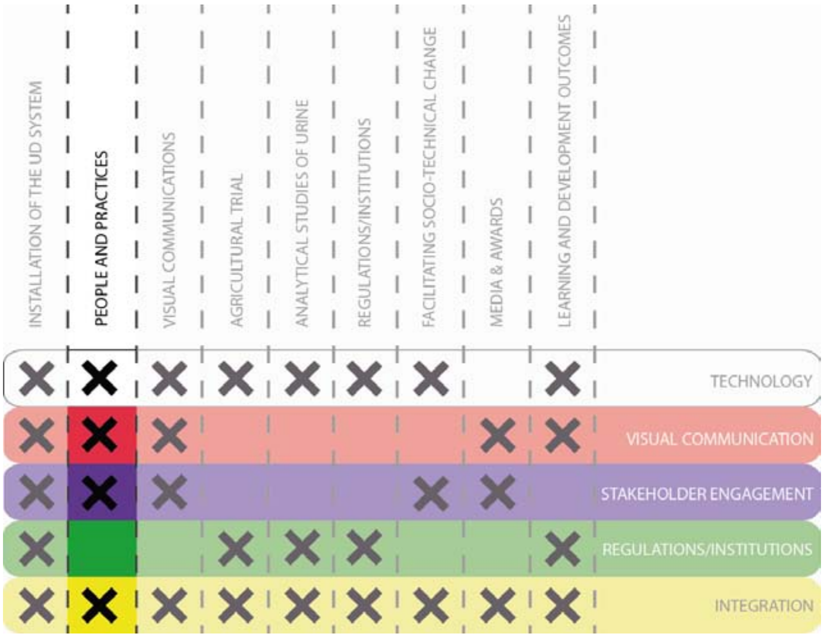
Jönsson, H, Stintzing, A, Vinnerås, B, & Salomon, E 2004, Guidelines on the use of urine and faeces in crop production, EcoSanRes Programme and the Stockholm Environment Institute, viewed 23 January 2011

E. Kvarnström, K. Emilsson, A. Richert Stintzing, M. Johansson, H. Jönsson, E. af Petersens, C. Schönning, J. Christensen, D. Hellström, L. Qvarnström, P. Ridderstolpe and J.-O. Drangert 2006. Urine Diversion - One Step Towards Sustainable Sanitation. EcoSanRes Programme, Stockholm Environment Institute, Stockholm, Sweden.

Schönning, C. and Stenström,T. A.. 2004. Guidelines of the safe use of urine and faeces in ecological sanitation systems. EcoSanRes, Stockholm Environment Institute, Swedish department for infectious diseases.

Von Muench, E., and Winker, M., 2009. Technology review on urine diversion components - Overview of urine diversion components such as waterless urinals, urine diversion toilets, urine storage and reuse systems. Deutsche Gesellschaft für Technische Zusammenarbeit GmbH (GTZ)

4 PEOPLE AND PRACTICES



'I always knew the engagement of end-users was going to be an important aspect of the UD trial…but it wasn't until we started getting feedback that I realised just how important! Our participants were not only enthusiastic but also incredibly insightful, critical and reflective in their feedback which more often than not came along with some witty toilet humour'

Dena Fam, Institute for Sustainable Futures, UTS

The personal nature of new sanitation concepts and the high level of intimate end-user interaction make social acceptance of any new toileting technology a critical factor for success. People and practices were therefore a key factor to consider in trialling UD systems at UTS. Capturing end-users' expert knowledge of the pragmatic everyday issues associated with using UD toilets helped to identify the viability of the UD systems in practice.

We learned early on in the UTS trial that UD toilet designs currently available on the market were less mature than expected, as discussed in the preceding chapters. Therefore the intrinsic motivation of users to support sustainability initiatives and accommodate the inconvenience of the technology (and the challenges associated with first generation technology) was critical in supporting the experiment. People involved in the UD trial were a self-selected sample of users from the floor of a UTS building occupied by the Institute for Sustainable Futures. The floor is shared with the Centre for Local Government that engages in research and practice, and where many members of staff have values that align with ISF's commitments to create change towards sustainable futures. The social space for the UD trial therefore consisted of staff, students, and visitors from both research centres – a 'non-average' and articulate group of participants who could formulate their own open-ended and conversational responses to the new socio-technical system and provide feedback on the viability of the system in practice.

To support the emergence of new practices and learn about the challenges of using the UD toilets in practice, a number of different social research tools were used:

1. *On-line survey:* Pre and post-installation surveys to capture changing perspectives of participants using the UD toilets

2. *Graffiti board:* A 'graffiti board' installed in washrooms over 8 months were used to capture commentary, questions and issues arising from using the UD toilets
3. *In-cubicle questionnaires*: questionaries conducted over 6 weeks investigated how technology and practices were implicated in the successful adoption of UD toilets
4. *A urinal usage study* to investigate how perceptions of privacy influence urinal use

4.1 PRE- AND POST-INSTALLATION SURVEYS

Anonymous surveys were conducted at different stages of the trial: (1) pre-installation to get some idea of how people used toilets at work e.g. do they sit on the toilet[21] and how much toilet paper did they use; (2) post-installation survey, one month after the first UD toilets were installed to capture participants' experiences in using the systems; and (3) eight months into the trial of the second toilet, to seek feedback on users' preferences and perspectives of the two toilet models installed. The surveys revealed that:

1. Participants had a range of practices in using toilets at work and depending on their cleanliness, the vast majority of male and female participants sat on toilet seats at UTS (80% and 70% respectively). Other less common practices included squatting, hovering and standing over the toilet. In using toilet paper, the vast majority of participants (95%) used under 0.5 metres. Feedback from one survey participant suggested there were practices not targeted in the survey and a need to consider different ways people used toilet paper, '*You could also ask if people wipe down the seats of toilets before sitting on them - this is additional loo paper that ends up in the toilet… Others make little seat covers out of paper, I've seen them left behind on seats :)'.*

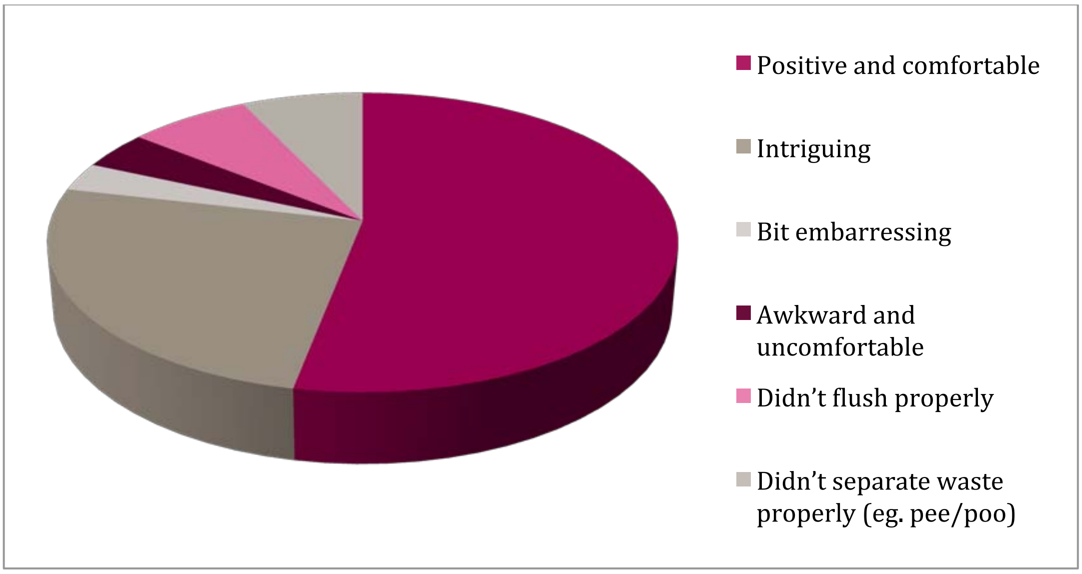


Figure 18: Experiences in using the UD toilets

2. One month after the installation of the UD toilets approximately 60% of participants were still using the UD toilet regularly (as opposed to using the conventional WC toilets). Even though our sample of participants reported that the overarching

---

[21] Some research suggests that few women sit directly on the seats of public toilets (Moore et al 1991) with recent investigations into the design of female urinals revealing less than 10% of female users in Athens sit on public toilet seats (Kyriakou, 2011).

experience of using UD toilets, was 'positive and comfortable', a significant number of participants noted that the system 'didn't separate waste properly' (see Figure 18).

3. After trialling two different models of UD toilets (Wostman and Dubbletten models), a survey was conducted to reveal user preferences of the two toilets, which each had its pros and cons (see chapter on *Installation of the UD system*). The survey revealed approximately three-quarters of the 18 participants who took part in the survey preferred the Dubbletten toilet. There were a range of reasons for this preference which included:
    - ease of use: *'I feel like I don't need to adjust so much and just can do my business';*
    - more efficient urine capture: *'…[it's] designed to maximise urine/phosphorous capture'* and
    - comments on the design of the toilet to flush toilet paper: *'…[Dubbletten is] designed better to guide the paper [placement]'.*

These closed-response surveys provide a useful quantitative snapshot of the broad landscape of the trial at a particular point in time. To gain a richer picture of the challenges and opportunities of trialling UD in practice, we sought open-ended, ongoing, qualitative feedback from users through commentary on the *graffiti board*.

4.2 THE GRAFFITI BOARD

The *graffiti board* was a qualitative feedback tool situated in the washroom (i.e. the separate room containing hand basins and hand dryers) to capture end-user comments and experiences of using the UD toilets. Designed by one of the visual communication students at UWS, Yana Mokmargana, the graffiti board asked one single question over the period of the trials with each toilet, *What do you really think about the urine diversion toilets? We want to know! Share your comments, reflections and arising issues in using the new toilet.*[22]

While the graffiti board was installed in both male and female washrooms, female participants provided significantly more feedback on the system than male participants. In the first month of the system being installed, females provided 188 comments in comparison to 44 comments from male participants. By the third month of the trial male participants had ceased to respond to the graffiti board altogether, unless prompted by the project team. This was in complete contrast to female participants who continued to comment on the system two years after the toilets were first installed. The project team decided to remove the graffiti board from the male washrooms after the initial stage of the trial, and continue the social research with female participants only, who continued to provide weekly feedback on the UD toilets for the following year[23].

---

[22] It is important to note that participants involved in the UTS trial were primarily researchers and administrative staff from the Institute for Sustainable Futures (ISF) and the Centre for Local Government (CLG). There is therefore awareness amongst participants of the value in trialling UD as a sustainable system of innovation as a way of contributing to its development. A particular interest in sustainable sanitation by staff at ISF most certainly contributed to the overwhelming success of the 'graffiti board' as a qualitative research tool.

[23] The limited feedback from male participants was in part due to the fact that male users were more likely to use the urinals rather than UD toilets to urinate, therefore had limited interaction with the UD toilets while in

Figure 19: End-user feedback mechanism - Graffiti board in-situ. (Designer: Yana Mokmargana, UWS)

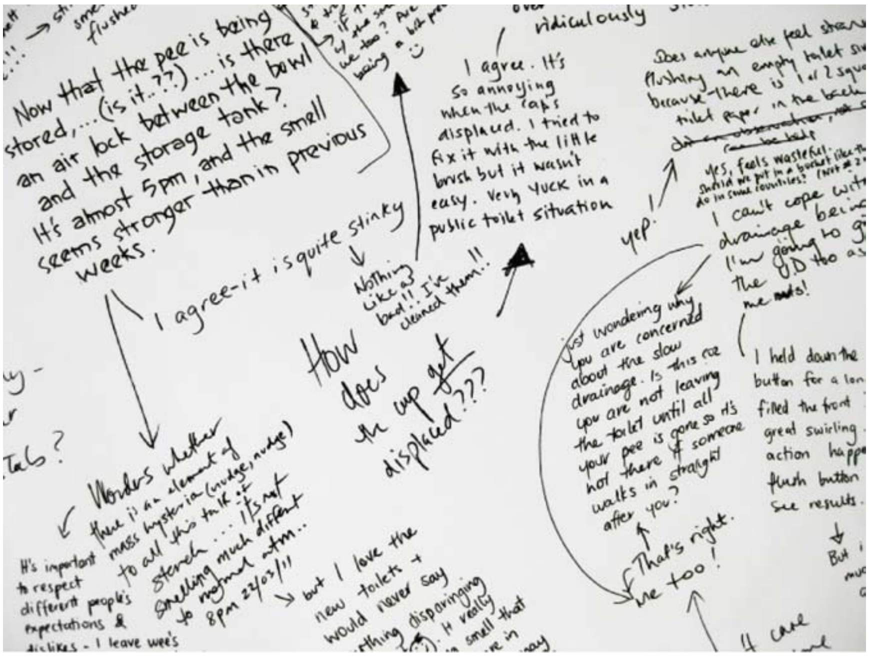


Figure 20: Example of conversational learning that occurred through the graffiti board

The design of the graffiti board enabled a communal space for 'conversational learning' (Kolb, Baker et al. 2002) to occur, in the form of written commentary while at the same time prompting conversation in which questions about the system were commonly answered among users themselves, rather than by the facilitators of the research. A new

---

the workplace. Male participants also communicated differently in that their replies were short and to the point in comparison to female comments which tended to be conversational in nature.

speech bubble poster was supplied each week, eliciting approximately 800 comments over eight months, and providing an incredibly rich record of conversational learning and insight into how users had modified their practices over the trial period.

User commentary ranged from disclosing experiences in using the toilets and problem solving to active inquiry into environmental and economic possibilities of the systems installed. From an operational perspective, users offered insights into system design, questioned the success of planned scale up and articulated thoughtful concerns about the long-term feasibility of the system in both public and private settings.

Participants provided valuable feedback on the challenges of adopting new practices in using UD toilets with commentary broadly falling into four distinct categories:

(1) Reflection on existing socio-technical practices - Where participants reflected on how new practices demanded by the new system aligned or not with existing practices. For example, one participant noted, *'I occasionally drop the toilet paper in the pee hole so have to think about placing it in the back-hole. This will be bad when I'm tired and not thinking'.*

(2) *Practical design advice and questions* – Where participants provided technical design advice to the researchers or asked explicit technical questions about the visible system and interface (see, for example, Figure 21). This feedback was both in visual and written form. For example, one male participant commented, '*Great concept, [but] this toilet is a little small for grown men'.* In addition, speculative questions on the broader system were asked by participants who sought to locate their novel experiences within a larger system change. '*Where will our pee go exactly? To a local farm? Where does the pee go after it goes through that hole? To a storage tank somewhere in the building?? Might be interesting to know more'.*

(3) Sharing new practices and insights – Where participants commented on their experiences or raised questions about the appropriateness and functionality of the technology relevant to the social setting of the trial. In questioning how best to use the toilet, a conversation between participants noted: (User 1) '*Hmmm…I sat back and still very messy for #2s Yuck ☹ (User 2) Me too, I wonder if depends on how well endowed your rear is? (User 3) Yeah – I found that I have to sit differently – way back. Intriguing! No big deal…'*

(4) Sustaining practices – Where participants shared particular insights about using the technology with the intention of supporting others' successful experiences and helping to overcome technical problems in sustaining fragile new practices. In discussing the process of changing habits and shared insights with each other; '*(User 1) …it might not be so hard to build a habit if it's your main (home) toilet. (User 2) I agree – after having a home urine diverting toilet for a year (and working from home!), I noticed when I went 'out' and used a normal toilet, the normal toilet started to feel strange (ie. I had to change my behaviour to use a normal toilet) (User 3) Yes a home toilet design would have to consider different bottoms and levels of dealing with the pee hole eg. kids, old people. How would a pee hole work with a commode over it? Or a kiddie seat'*

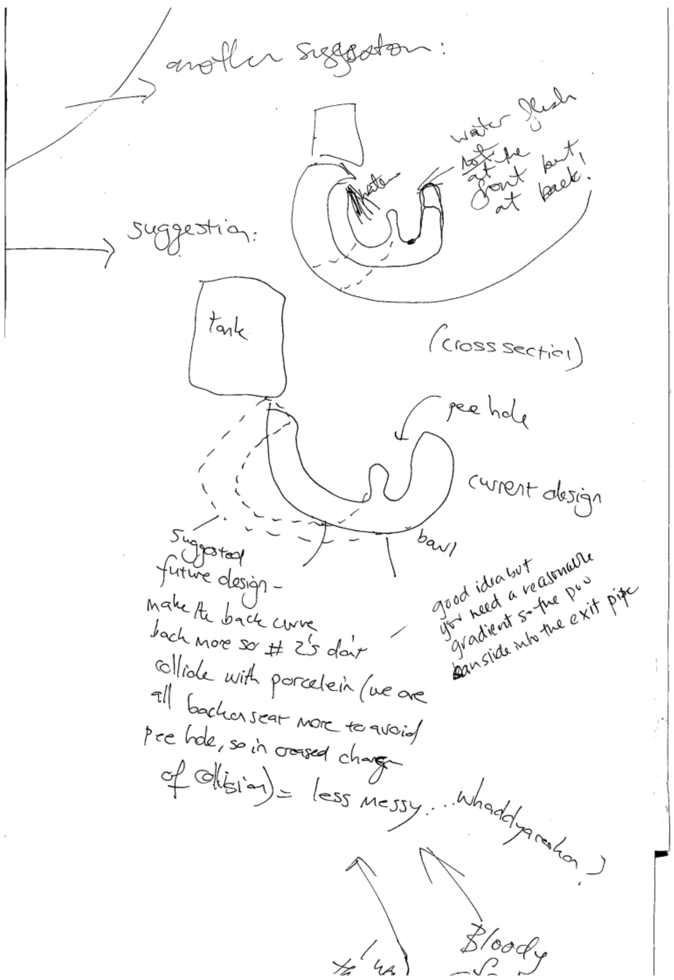


Figure 21: Design advice and commentary contributed to the graffiti board in the women's toilet in the early stages of the trial

The degree of enthusiasm in which end-users were engaged in the UTS trial was wonderful. On fixing the issue of slow drainage of the Dubbletten toilets for example, commentary was immediately added to the graffiti board, one participant commenting, *'Fantastic! What an amazing improvement, makes me want to drink more so I can pee more!'* and another happy toilet user, noting the speed of drainage in the toilet commenting, *'The Phantom Pee: it's so fast you can't' even see him/her!'* (see Figure 12 in chapter on *Installation of the UD system*). The sense of good humour and tolerance in which end-users participated in the trial contributed enormously to the quality of feedback in the trial.

While the graffiti board provided a way of capturing open-ended commentary, the final method of data collection, in-cubicle questionnaires, provided a way of capturing specific aspects of toileting practices e.g. finding out how users flushed the UD toilet and how toilet paper was used.

4.3 IN-CUBICLE QUESTIONNAIRES

We included questionnaires within the toilet cubicles to find out specific details of practices. The initial motivation for their inclusion came about as a result of testing the Wostman toilets against Australian standards and discovering the toilets failed the standard 'flush test' (see chapter on *Installation of the UD system*). Successful toilet flushing reflects an overlap of 'practice' and 'technology' with the UTS trial revealing that technical performance depends very much on people's practices. We therefore asked a range of questions to determine the effectiveness of the flushing mechanism as a function of different practices (e.g. the amount of toilet paper used, the length the flush button was held down etc.) (see chapter on *Installation of the UD system* for details).

Figure 22. Images of the toilet paper trial

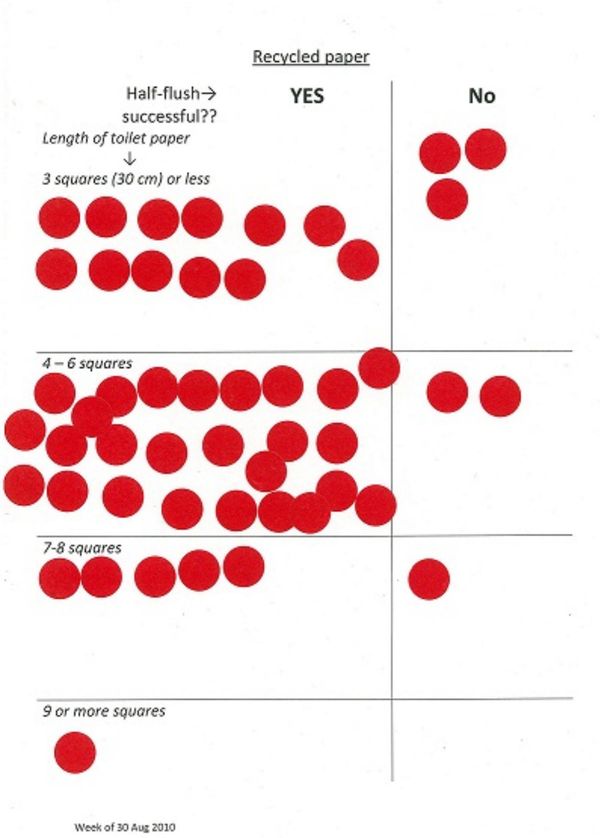


Figure 23: A sample questionnaire determining how much recycled toilet paper was used and if it was effectively flushed away

In addition to questions on the effectiveness of the flushing mechanism, in-cubicle questionnaires investigated whether participants used the flushing mechanism for the urine bowl (in Dubbletten model) and why. The urine flushing mechanisms for the

Dubbletten UD is not a feature present in other UD toilet models, we therefore wanted to explore the reasons for its use. What was revealed was that not all users used the flushing mechanism and that it was primarily used to ensure the urine bowl was clean before leaving the toilet cubicle.

In-cubicle questionnaires also investigated whether paper was flushed away effectively (See Figure 23) and what type of toilet paper was preferred (see **Figure 22**). The toilet paper trialled included recycled paper, single ply paper and double ply toilet paper. With the majority of toilet users working at the Institute for Sustainable Futures, with work commitments to sustainability it was not surprising that the most popular toilet paper type was 'recycled paper' (see Figure 24).

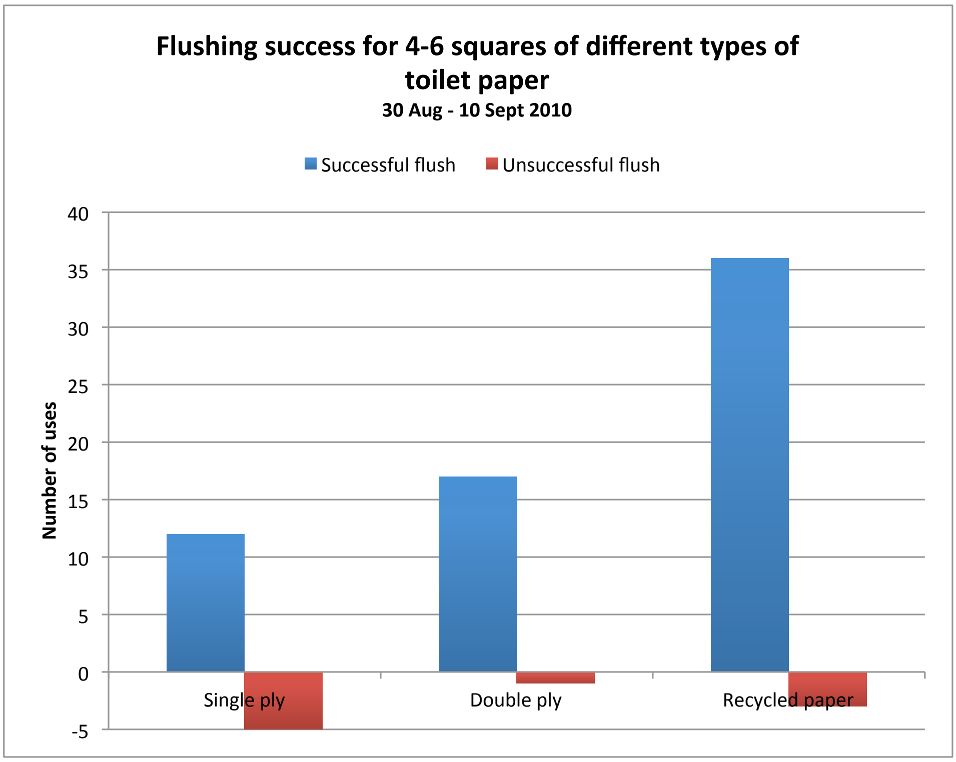


Figure 24: Summary of results for success/failure of flushing a specific length (4-6 squares) of different varieties of toilet paper tested

The in-cubicle questionnaires revealed a range of different practices in use for the Wostman toilets and helped participants reflect on their own practices. For example, one participant commented, *'I'm finding this [in-cubicle questionnaire] a really good awareness raising tool. I never put any thought into how many squares of loo paper I was using – now I think about it to see if I really need it…'*

4.4 URINAL USAGE STUDY

Male participants of the UD trial commented on the preference for using urinals as opposed to the UD toilets to urinate. For example, one male participant commented, '*I'd rather just use the urinal'* and another participant questioned the viability of collecting urine from a UD toilet commenting, '*Wouldn't it make more sense to [divert urine from] the urinals?'*

Discussing male participants' feedback on the use of urinals with the project team revealed an intriguing question about whether male toilet users really did prefer urinals to toilet cubicles for urinating. In answering this question our methodology evolved to include a collaborative endeavour with the property developer, Lend Lease, where a survey was developed to determine male users' preferences for urinals and whether privacy screens between urinals would increase urinal usage (as opposed to using toilet cubicles for urinating). In total 162 male Lend Lease employees located in Australia, America, Asia and Europe between the ages of 20-65+ were surveyed. This survey included questions about how often participants choose to urinate in cubicles as opposed to urinals; the reasoning behind their choice to use cubicles; whether privacy screens would increase urinal usage.

The survey revealed that most men prefer to use a urinal, with only 25% who 'often' or 'always' preferred to use a cubicle. For reasons why men used cubicles to urinate, 24% cited privacy (this group correlated to respondents who said they 'often' or 'always' used the cubicle), 19% chose the response "using urinals alongside my workmates makes me uncomfortable", while 52% chose "the urinals are occupied".

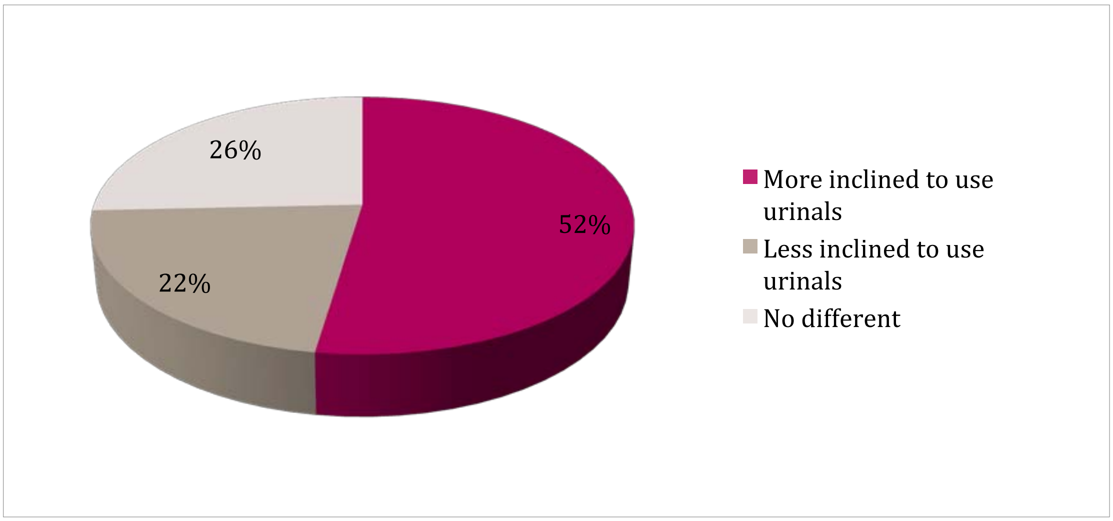


Figure 25: Representation of whether male uses would be more inclined to use urinals if privacy screens were installed

A key outcome from the surveys was that approximately half of male users claimed that they would be more inclined to use urinals if privacy screens were installed (Figure 25). This result included 5% of participants admitting discomfort in urinating beside workmates and 24% preferring privacy which could reflect, for example, perceptions of inadequate space between urinal stalls. The implication of this finding is that installing privacy screens between urinals has the potential to increase urinal usage and therefore potentially contribute to reducing water consumption.

While this analysis of urinal usage was not originally planned for the UTS trial, the outcome from this research triggered us to monitor the urinal use in our urine capture trial. Once the urinals were installed, electronic monitors were used to track the rate of use between the two urinals over 18 weeks. Monitoring the usage of both urinals before the installation of partitions revealed a clear difference in the rate of usage between the two urinals (see Figure 26 below). The urinal closest to the entrance and relatively more protected from the view of incoming traffic (Urinal A) had significantly higher frequency of use, (on average between 25- 50%) than the urinal (Urinal B) furthest from the entrance and more visible to incoming traffic.

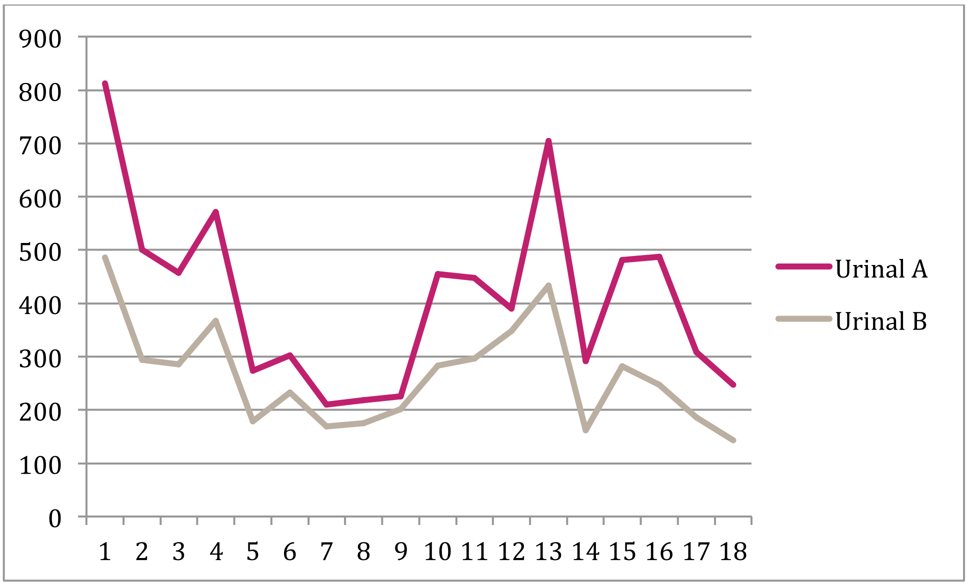


Figure 26: Urinal usage from two waterless urinals over an 18 week period before installing partitions

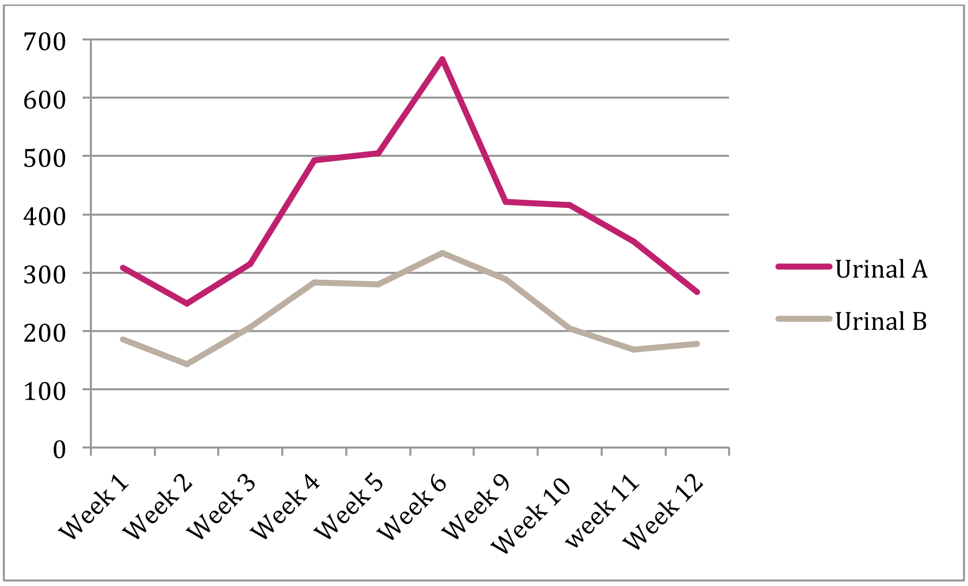


Figure 27: Urinal usage from two waterless urinals over an 18 week period after installing partitions

The survey data conducted with Lend Lease employees led us to hypothesis that a more even rate of usage in the urinals would occur after installing the partitions, with the privacy afforded by partitions. In fact, we found that urinal usage of the two urinals remained the same (Figure 27) e.g. urinal A protected from incoming traffic still had significantly higher frequency use (between 20-50%) than urinal B which is more exposed in incoming traffic (apart from an extreme change in usage which during week 7 and 8 when one of the urinals of taken out of operation for maintenance; these weeks have been omitted from Figure 26).

Surprisingly, the partitions made little difference to the urinal usage rates but without qualitative data to substantiate these claims, it is difficult to interpret these results. This may be due to the fact that the urinal block was a relatively small site, containing only 2 urinals, and users were primarily students and café patrons which present a very different cultural environment to feedback garnered in the Lend Lease survey.

4.5 SUMMARY

In summary, the design of the social research in the UTS trial was innovative in that it drew upon a range of qualitative and quantitative methods to capture feedback from end-users in a reflective process of action research. Insightful comments from end-users enabled the research team to make pragmatic improvements, as well as to draw conclusions about the potential for UD toilets in public and residential settings.

ACKNOWLEDGEMENTS

We would like to thank the following people for their valuable contributions to the research in this chapter.

- *Abby Lopes,* Senior Lecturer at the School of Humanities and Communication Art, UWS. Abby organised and supervised 3rd year students from her graphic design course to create the primary feedback tool used in the project.
- *Our funny dunny users,* for participating with good humour and enthusiasm, and for their preparedness to share quite personal reflections and insights.
- *Nick Storey and male staff,* Lend Lease, for his assistance and enthusiastic permission to conduct the international survey of privacy perceptions amongst urinal users.

REFERENCES

Moore KH, Richmond DH, Sutherst JR, Imrie AH, Hutton JL. 1991. 'Crouching over the toilet seat: prevalence among British gynaecological outpatients and its effect upon micturition.' Br J Obstet Gynaecol. 1991 Jun;98(6):569-72. (abstract at http://www.ncbi.nlm.nih.gov/pubmed/1873247)

Kyriakou D., 2011, We know squat about women's urinals, World Plumbing Connection, http://www.worldplumbinginfo.com/article/we-know-squat-about-female-urinals [accessed 16th Sept, 2011]

5 VISUAL COMMUNICATIONS

'I think the designer…is working for another public, that is the user or the citizen, and you want to create a clear path for them to understand issues (such as urine diversion and phosphorus recovery) so they can choose to act or not to act. It's not actually us persuading them…(but rather us informing, guiding and prompting them to think differently about the world)'

Jennifer Williams, Senior Lecturer, Design Building and Architecture, UTS

From its inception, the UTS trial employed visual design as a core element of the process and content to facilitate the socio-cultural transition to a new and unfamiliar system of sanitation. At the start of our project, a global scan revealed the intriguing fact that user participation in experiments trialling UD systems elsewhere had been very limited. We saw design – particularly visual communications design – as an important enabler of this participation.

The visual communications strand of research was closely allied with the stakeholder engagement strand. During the investigation phase, the strand tasked itself with creating highly visible and accessible tools that would help to configure what system change might look and feel like for the everyday user. While other disciplines of design had significant roles to play in the retrofit of the system (e.g. engineering and plumbing), the project team hypothesised that visual communications design had a critical role to play in introducing the issue of nutrient recovery and reuse into the public imagination. This required preparing the ground for a taboo subject to be broached and strong support for changing highly personal and deeply embedded practices of toilet use. In achieving this, designers needed to take into account the complex problem space in which standards of comfort, cleanliness and convenience (Shove 2003) were disturbed and challenged.

In the investigation phase of the project, visual design students across two universities (UWS and UTS) generated initial visual concepts. Students were asked to consider how to 'give voice' to the UTS trial; to invite end-user participation; and to explain the closed loop system of the trial as well as the phosphorus cycle, the current situation of phosphorus depletion, and in the process facilitate debate about the issue of waste as a resource.

The inclusion of visual communications design in the trial emphasised the importance of collaboration over individual action. This was supported by the fact that student design teams were dependent on expert knowledge provided by the transdisciplinary project team and the structure of the project to facilitate collegial collaboration between the research strands and partners through the integration strand. One of the important outcomes from the UTS trial was the prioritisation of potential visual communication strategies and deliverables across the three stages of the project. This provided a way for visual communications design to contribute to the project's dissemination and up-scaling and a clear line of action for transdisciplinary collaboration in the project (Lopes, Fam et al. 2012).

A range of multimedia works were created by students involved in the UTS project including animation, web design, logo development, feedback tools and systems diagrams. One of the animations designed by UTS student Dylan Thomas won the Australian Graphic Design Awards with his animation on Peak Phosphorus (See chapter on *Media, Publications and Awards* for details). The animation is available at: http://vimeo.com/13365354. The following section presents a small selection of student work created for the UTS trial. Rebecca Lam's (UTS) information design, 'Thank you for your Pee' was created for toilet paper showing why mining of phosphorus needs to be reviewed (See Figure 28), based on '8 reasons why we need to rethink the management of phosphorus in the global food system' (Cordell 2010). 'Thank you for your pee' appears on every second sheet of each roll and was designed to be printed on toilet paper for the UTS trial to facilitate end-users engagement with the concept of Peak Phosphorus and consideration of urine diversion as a means of recovering phosphorus from urine.

To engage male users in the UTS trial, Jethro Lawrence (UTS) created an interactive design to prompt male urinal users to reflect on the value of urine capture and reuse in closing the phosphorus cycle locally. Jethro's interactive systems design achieved this with the clever use of a heat sensor attached to the urinal which would be triggered when a participant used the urinal. As a consequence of using one of the urinals a simple animation sequence would be triggered in the light box above the urinal. The animation aimed to inform the user of how they have contributed to closing the phosphorus cycle by contributing their urine to planned agricultural trials. While the interactive design was not physically produced for the UTS trial, a modified version of the design was printed and installed on the back of UD toilet doors so toilet users were informed about the relationship between them and phosphorus cycle.

5.1 LOGOS, SYSTEM DIAGRAMS AND INTERACTIVE DESIGN

Figure 28: 'Thank you for your pee'. *Designer: Rebecca Lam, UTS*

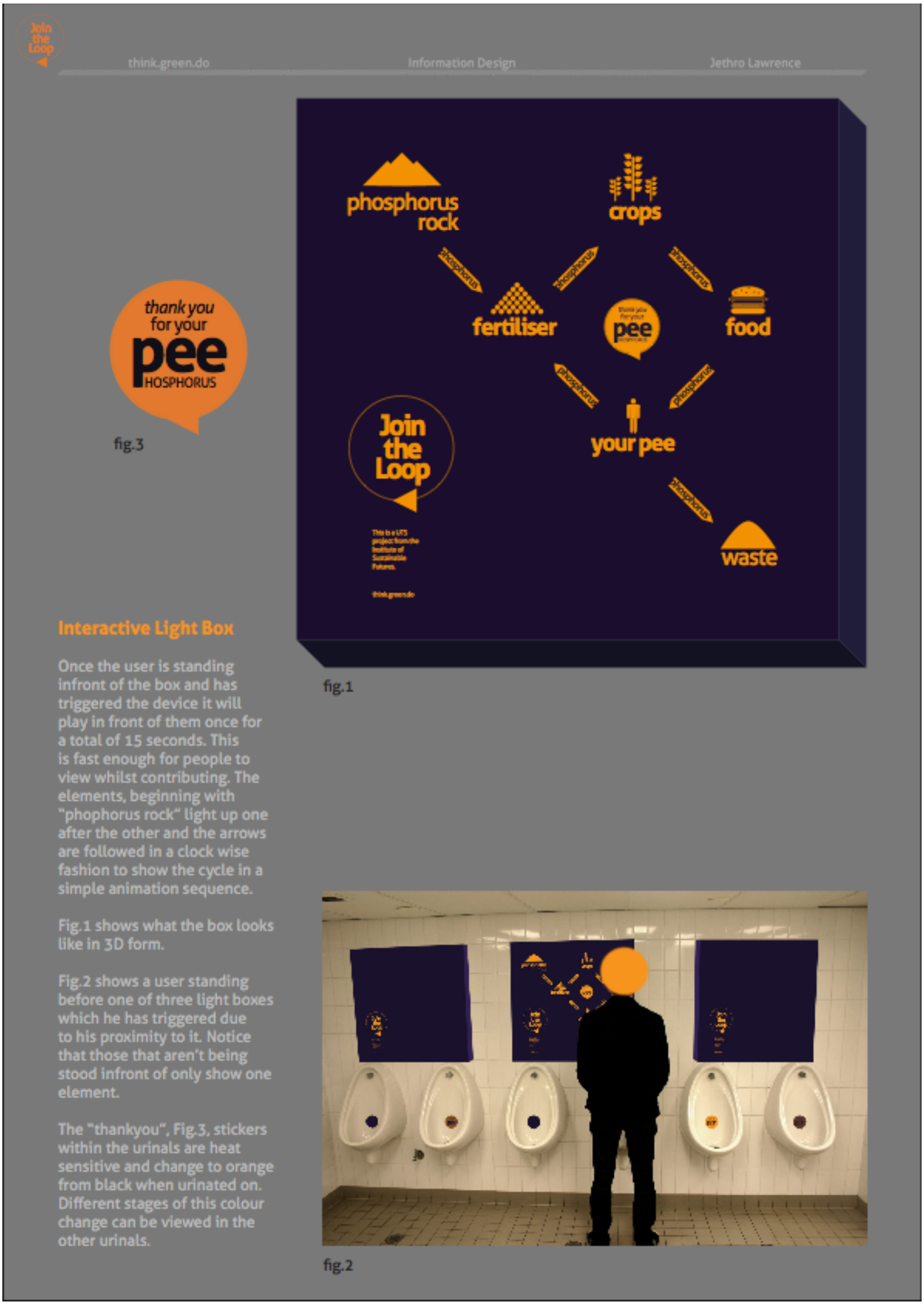


Figure 29: 'Thank you for your pee' heat sensitive sticker, a still of 'closing the loop' cycle, and 'in situ' as motion sensor in front of urinal. *Designer: Jethro Lawrence, UTS* (A modified version of the 'still' in fig. 1 above was produced for the back of each toilet door involved in the UD trials at UTS).

A range of different logos were produced for the UTS project, with one amongst many of the evocative logos depicting urine drops in the appropriately named emblem – Phos4us. Interpretations of the logo were anticipated to be used in a process of 'culture jamming'[24]. The intention was for small printed urine drops to be distributed throughout the campus to trigger the imagination of students, staff and visitors and draw attention to the UD trial. Placement of the 'urine drops' was to be designed to lead users to the UD toilet block. When our intention for the trial changed track, away from a public trial to a more protected pilot, the culture jamming concepts were put on hold.

The basic design of the logo Phos4us was also incorporated into a system diagram (See Figure 29) to inform users of the phosphorus cycle from mine to field to fork to toilet. The visual representation of the phosphorus cycle has the potential to engage users in the issue of phosphorus recovery from urine in a fun and non-threatening way.

In an attempt to encourage users to use the UD toilets correctly students developed a range of visual 'how-to' guides. These included diagrams encouraging male users to sit when urinating and used humour as a device to engage users in changing their practices in using UD toilets (See Figure 31 and Figure 32)

[24] Culture jamming is a form of disruption that plays on the emotions of viewers by disrupting the unconscious thought process that takes place when viewers see advertisement. Activists utilise an image to draw out emotional responses from people and evoke some type of reaction. The reactions that most cultural jammers are hoping to evoke are behavioral change and political action.

Figure 30: Phos4us systems diagram, ***Designer: Mark McLoughlin (UWS)***

Figure 31: Encouraging male users to sit down to use the UD toilets, Designer: Peter Zhu (UWS)

**Figure 32: 'How to use the UD toilets',
Designer: Yana Mokmargana, UWS**

Summary

Enormous importance was placed on engaging end-users in the UTS trial through design-oriented strategies. From the earliest planning stages of the trial the visual communications strand was involved in producing a range of innovative design interventions to engage end-users (and others connected to the trial) through systems diagrams, logos, interactive designs and feedback tools. Team members in this strand of research were strong advocates for the agency of design to facilitate transitions toward sustainability. Visual communication tools were therefore used to not only inform participants about the 'how and why' of the system but also to gather data on perceived challenges, insights and reflections by end-users through the trial (See chapter on *People and Practices* for details on the design tools used to gain feedback form end-users).

ACKNOWLEDGEMENTS

We would like to thank the following academics for their valuable contributions to the research in this chapter.

- *Abby Lopes,* Senior lecturer at the School of Humanities and Communication Art, UWS. Over two semesters of the project Abby organised and supervised 3rd year students from her graphic design course to contribute systems diagrams, logos, feedback tools and web design for the project.
- *Jennifer Williams,* Senior Lecturer at the School of Design, at UTS has significantly contributed to the UTS trial by involving students over two semesters of the project to contribute way finding devices, interactive design tools, systems diagrams and logos for the project.
- *Shankar Sankaran,* Associate Professor from the School of Built Environment, UTS provided conflict resolution strategies and supported systems thinking within the project and visual communications strand

REFERENCES

Cordell, D. 2010. *8 reasons why we need to rethink the management of phosphorus resources in the global food system*. Global Phosphorus Research Initiative Information Sheet 1. http://phosphorusfutures.net/files/1_P_DCordell.pdf

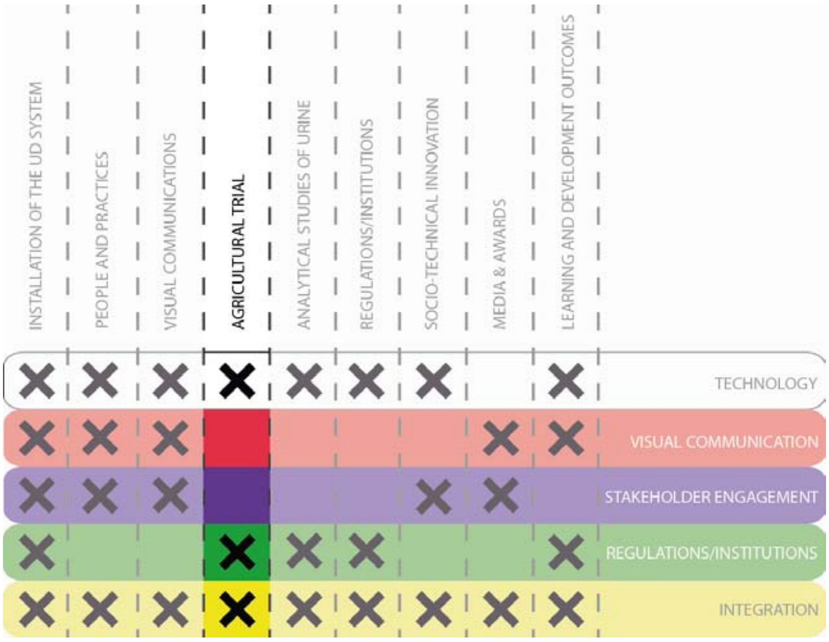
Fam, D. & Mitchell, C. 2013. Sustainable innovation in wastewater management: Lessons for nutrient recovery and reuse. Local Environment.

Gwilt I. & Williams J. (2012), Framing futures for visual communication design research, Design Principles and Practices

Meadows, D. (1999) Leverage points: Places to intervene in a system. Hartland, VT: Sustainability Institute.

Lopes, A., Fam, D.M. & Williams, J. 2012, 'Designing sustainable sanitation: involving design in innovative, transdisciplinary research', Design Studies, vol. 33, no. 3, pp. 298-317.

6 AGRICULTURAL TRIAL



'I'd like to hold a flower in my hand produced from the product from our project and be able to say that it's no different from flowers produced with (commercial) fertilizers'.

Shankar Sankaran, Associate Professor from the School of Built Environment, UTS

(Shankar's vision of the impact of the project)

To move UD beyond a small scale niche practice to larger scale adoption more broadly within society, there needs to be a market for urine – a demand for urine that ascribes a value to it as a crop nutrient and/or other products. For this to happen, the efficacy of urine as an agricultural nutrient needs to be established. While studies on the efficacy of urine have been carried out elsewhere[25], the UTS project included a small local demonstration aligned with our intent to open the space for further research and practice.

Having research team members from the agricultural school at the University of Western Sydney (UWS) and Nursery and Gardens Industry Australia (NGIA) provided the context to involve a student in practice-based learning[26], to test the efficacy of urine as a fertilizer while fulfilling the requirements for the Bachelor of Agriculture (Honours) degree. The final year honours research project was designed to build on previous studies while adding elements of original research.

6.1 INNOVATIVE ELEMENTS IN THE TRIAL

The first step in the study was a literature review, which revealed that urine studies elsewhere have typically focussed on edible crops. Furthermore, the response of plants to urine application has been measured using *crop yield* – namely the amount of total above-ground plant matter, dried and weighed. In designing the experiments for this study, two

[25] For example, Kirchmann & Petterson 1994; Pradhan, Holopainen & Heinonen-Tanski 2009; Pradhan et al. 2007.
[26] See Acknowledgements at the end of this chapter for research collaborators involved.

elements of original research relative to the literature were introduced: to include non-edible plants in the study, and to use an additional measure of plant response to urine.

The innovative elements and rationale for inclusion were as follows:

1. Urine was trialled with three different classes of plant species: an edible crop, an exotic ornamental, and an Australian native. Since health regulators expressed concerns about potential health risks from pharmaceutical residues in urine (see chapter on *Regulations and Institutions*), we were interested in the potential for urine to meet the nutrient needs of non-edible crops, on which the urine market would depend, at least initially. Amongst non-edibles, ornamentals and Australian natives are a significant market segment of the local nursery and garden industry hence urine response with this group was also of interest to our NGIA research partners. While Australian natives have evolved to grow in soils with very low phosphorus concentrations and are generally known to show little response to the addition of phosphorus, testing the response to urine in a representative of this class was of interest to re-confirm or question this characterisation of natives.

2. The response of crops to urine was measured through two metrics: (1) crop yields, and (2) the concentration of nutrients (P and other key nutrients) accumulated in leaf tissue. Measuring the concentrations of key nutrients in a plant's leaf tissue shows how well nutrients have been taken up relative to the application rate of nutrients. Leaf tissue concentrations also allow us to estimate whether the plant has obtained sufficient amounts of nutrients. Critical concentrations of different macro and micro-nutrients in leaf tissue for many plant species have been published, where 'critical concentration' is the concentration below which the plant is deemed to be deficient in that nutrient. Comparing the leaf tissue concentrations of nutrients in urine-fed plants with published values of critical concentrations for these plant species allows us to identify what nutrients are lacking and need to be supplemented.

Figure 33: Pot trials in greenhouse at UWS School of Sciences and Health

6.2 EXPERIMENTAL SET UP

The primary aim was to compare the bio-availability of phosphorus in urine, compared with a more conventional fertilizer source. The experiments also sought to evaluate the bio-availability of other nutrients in urine, and verify the link between urine application and soil salinity in published literature.

Two sets of experiments were conducted with the test plants grown in pots in the controlled environment of a glasshouse. Each experiment lasted 50 days and used the three plant species:

- *Lettuce (*major horticultural crop *Lactuca sativa)*
- *Pelargonium* (exotic and ornamental *Pelargonium x hortorum*)
- *Kangaroo Grass* (Australian native and ornamental *Themeda Australis*).

In the first experiment, six progressively increasing quantities of phosphate fertilizer (NaH_2PO_4 in analytical reagent grade metal salts form) were added to the potting mix, and after a brief 'resting period', the pots were planted with the test species. The application rates of phosphate varied from 0 to 100 mg/pot of elemental P. This experiment provided a baseline.

In the second experiment, progressively increasing quantities of urine were applied instead of phosphate fertilizer. The urine was supplied from the UTS urine diverting toilet (female block) which had been stored for two months prior to being transported to UWS following required biosafety protocols[27]. The stored urine was analysed just before transport to UWS, so the urine nutrient profile was known at the start of the experiments[28]. The maximum amount of urine applied was set to match the nitrogen in the first experiment (400 mg/pot), as recommended by Jönsson et al. (2004). Given the urine nutrient profile, this translated to a maximum of 60 mg/pot of elemental P. Like the first experiment, urine was applied to the potting mix at the beginning, with rates varying from 0 – 200 ml/pot.

Both experiments used a standardised potting mix with a non-limiting basal dressing of the remaining macro and micronutrients[29] so that variation in plant responses could be attributed to rates of phosphate or urine addition. Each application rate for phosphate and urine was replicated in four pots of each plant species, and statistical averages used in reporting.

Salinity measurements were conducted on soil in both experiments following a standard methodology in the agricultural discipline. The literature indicates that urine application leads to an increase in soil salinity. Soil salinity is detrimental to both soil health as well as plant growth, so it is important to limit salinity to safe levels.

---

[27] Urine is 'treated' by storing it for a period to allow pathogens to die, and is consistent with World Health Organisation (WHO) guidelines for urine re-use (WHO 2006). See *Regulations and Institutions* chapter for other details of biosafety protocols .

[28] Some further nitrogen losses can be expected between the time of analysis and the application to the pots, so the quantification of nitrogen may not have been reliable.

[29] These included nitrogen, potassium, calcium, magnesium, zinc, copper, manganese, and boron.

6.3 PLANT RESPONSE TO APPLIED URINE AND PHOSPHATE

6.3.1 Comparison of crop yield (mass of plant matter)

Figure 34 below shows the yield (measurements of dry mass after 50 days) from the experiment with urine application. The graphs from the first experiment with phosphate application showed similar trends to those in Figure 34, and are not shown here.

Key observations:

- *Lettuce* was very responsive to applied rates of both phosphate and urine. The increase in biomass was approximately linear and did not plateau in either experiment. The yield with maximum phosphate (100 g/pot) was 16g, higher than with yield of 14g with maximum urine applied (200ml/pot). However, when the results are compared relative to elemental P applied, the yield for lettuce from urine application was higher than the yield from phosphate application. This suggests that for lettuce, there is better plant availability of nutrients in urine than conventional fertiliser.

- *Pelargonium* biomass was responsive but to a lesser degree than lettuce. The yield initially increased and reached a plateau before maximum application rates of both phosphate and urine, with maximum reached with urine earlier. This demonstrates that pelargonium requires significantly less nutrients than lettuce.

- *Kangaroo grass* had no significant response in either experiment, confirming low P nutrient requirement concluded from other studies of Australian natives.

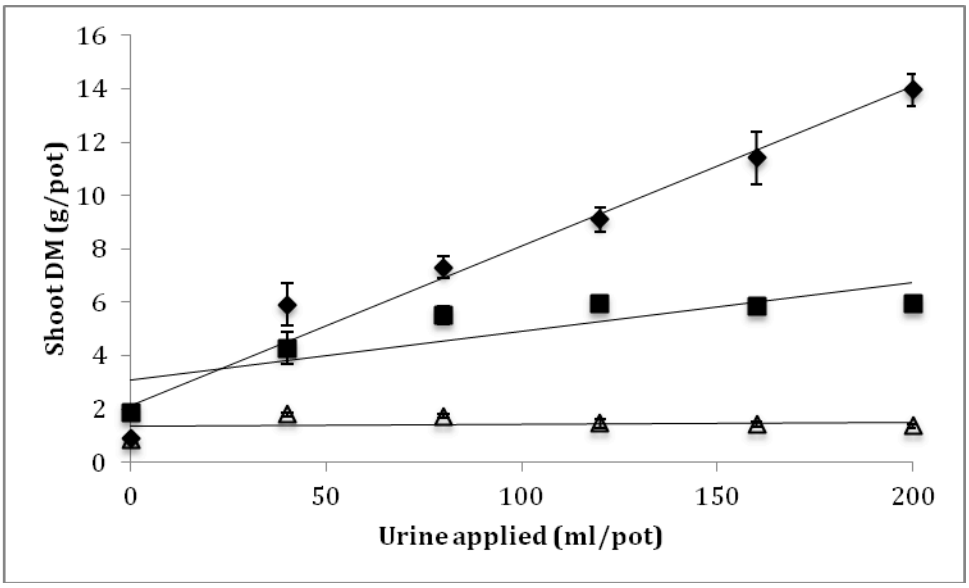


Figure 34 : Crop yield (dry mass) with urine application for lettuce (diamond data points), pelargonium (squares) and kangaroo grass (triangles)

6.3.2 Comparison of nutrient take-up by plants (concentration in leaf tissue)

6.3.2.1 Take-up of Phosphorus from urine verses phosphate fertilizer

Concentrations of P in leaf tissue measured in lettuce with applications of phosphate and urine are shown in Figure 35. The graphs for pelargonium showed similar trends as for lettuce in Figure 35.

Key observations:

- For both lettuce and pelargonium, the rise in concentration of P in leaf tissue was more rapid when the phosphorus was supplied from urine rather than phosphate. That is to say P in urine is utilised more efficiently than P in phosphate fertilizer.

- For lettuce, sufficiency in P (i.e. the critical concentration shown by dotted line) was reached more quickly with urine (20 mg/pot) compared to phosphate (43 mg/pot). For pelargonium, all applications of urine and phosphate provided sufficient P.

- No significant response was observed with kangaroo grass in either experiment. Interestingly, the plant tissue concentration of P in kangaroo grass of 0.3%, compared to the maximum P concentrations observed with pelargonium (0.3%) and lettuce (0.8%) with external supplies of P confirm the amazing nutrient efficiency that this Australian native species has developed. That is, it is not that this Australian native has less P in its tissue than other species, but rather that it has an extraordinary capacity to take up P from very low feed concentrations.

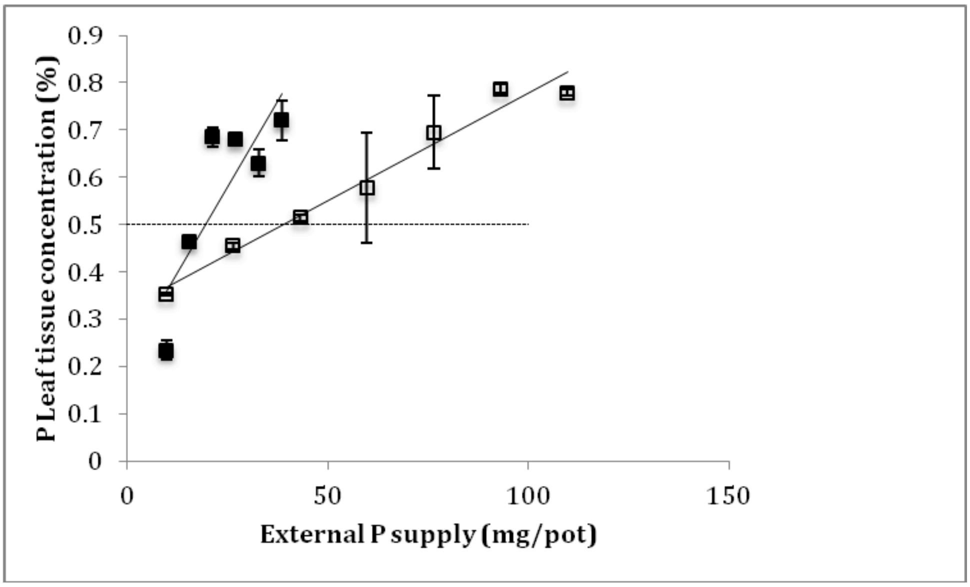


Figure 35: Concentration of P in lettuce leaf tissue with application of urine (black squares) and phosphate (white squares)

6.3.2.2 Take-up of other nutrients from urine

Analysis for remaining macro and micro nutrients (N, K, Ca, Mg, Zn, Cu, Mn, B) showed that the urine applications that provided the critical concentration of P simultaneously provided adequate levels (equal or above critical concentrations) of all other key nutrients except nitrogen (N). Phosphate fertilizer supplied adequate levels of all the measured nutrients. Since the full application rate for urine was chosen to match the 'adequate' N levels in the first experiment, it is no surprise that the lower quantities of urine application led to deficiency in N.

6.4 SALINITY IMPACT OF URINE APPLICATION

Soil salinity, or the presence of excess salts, can hinder the absorption of water from the root zone through osmosis, leading to moisture stress in plants. An imbalance of competing ions under saline conditions can lead to reduced absorption of key nutrients. It can also affect the physical structure of soil. While the 'acceptable' level of salinity is not straightforward to determine as it depends on a variety of factors including soil type, irrigation practice and vegetation type, the literature review suggested that salinity levels of 0-2 dS/m (or below 0.02 dS/cm) are considered safe (Richards 1954; Abrol, Yadav & Massoud 1988).

Figure 36 below shows the change in salinity measured in the pots across the range of application levels of phosphate and urine, where '1' is the lowest and '6' is the highest application. It confirmed findings elsewhere, that soil salinity is significantly affected by urine application, but not by phosphate application.

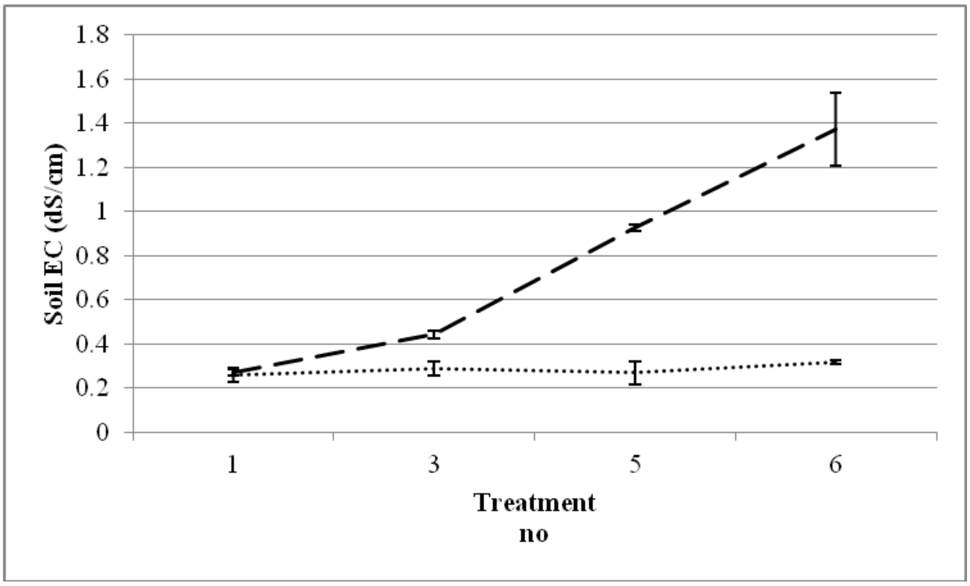


Figure 36: Changes in soil salinity (electrical conductivity) with increasing application of phosphate (dotted line) and urine (dashed line)

It should be noted that the pot experiments show higher EC measurements than would be found from phosphate or urine application in rain-fed and/or irrigated field experiments, where salts such as sodium would be removed over time through leaching.

6.5 CONCLUSIONS

The study showed that lettuce and pelargonium took up phosphorus from urine more efficiently than from conventional fertilizer. For the same level of external application of elemental P, both crop yield and P concentration in leaf tissue was higher when supplied by urine. This confirmed the conclusion that urine provides highly plant available forms of P (Jönsson et al. 2004).

At the full application rate of urine, lettuce and pelargonium showed nutrient adequacy for all the macro and micro nutrients measured, but at lower application rates, N deficiencies appeared.

The study identified the need for strategies to manage soil salinity impacts from urine application while usefully utilising urine nutrients. It points toward two different lines of inquiry. The first is to use lower amounts of urine in combination with supplementary nitrogen fertilizer application. This would be designed to allow adequate P and other macro nutrients to be supplied from urine, and nitrogen sufficiency to be met by the nitrogen fertilizer, while keeping soil salinity within safe levels. The second is to trial different combinations of application and irrigation procedures, with a particular focus on leaching fractions.

ACKNOWLEDGEMENTS

We thank the following individuals/organisations for their valuable contributions to the research reported in this chapter:

- *Mr Thomas Venables*, Agriculture Honours student at UWS, who conducted this research for his thesis (Venables, 2011).
- *Prof Bill Bellotti* (School of Natural Sciences, UWS) for supervision of the research
- *Dr Anthony Kachenko* (Nursery & Garden Industry Australia) for co-supervision, and for contributing additional financial support, alongside UTS, to fund the experimental and analytical expenses.
- Sydney Water for the analysis of urine used in the experiments.

REFERENCES

Abrol, IP, Yadav, JSP & Massoud, FI 1988, *Salt-affected soils and their management*, vol. 39, FAO Soils Bulletin, Food and Agriculture Organization of the United Nations, Rome.

Jönsson, H, Stintzing, A, Vinnerås, B, & Salomon, E 2004, Guidelines on the use of urine and faeces in crop production, EcoSanRes Programme and the Stockholm Environment Institute, viewed 23 January 2011, <http://www.netssaftutorial.com/fileadmin/DATA_CD/04_Step4/SE5._Guidelines_on_the_use_of_urine_and_faeces.pdf>

Kirchmann, H & Pettersson, S 1994, 'Human urine - Chemical composition and fertilizer use efficiency', Nutrient cycling in agroecosystems, vol. 40, no. 2, pp. 149-154.

Pradhan, SK, Holopainen, JK & Heinonen-Tanski, H 2009, 'Stored human urine supplemented with wood ash as fertilizer in tomato (Solanum lycopersicum) cultivation and its impacts on fruit yield and quality', Journal of agricultural and food chemistry, vol. 57, no. 16, pp. 7612-7617.

Pradhan, SK, Nerg, A-M, Sjöblom, A, Holopainen, JK & Heinonen-Tanski, H 2007, 'Use of human urine fertilizer in cultivation of cabbage (Brassica oleracea)and its impacts on chemical, microbial, and flavor quality', Journal of agricultural and food chemistry, vol. 55, no. 21, pp. 8657-8663.

Richards, L 1954, 'Diagnosis and improvement of saline and alkali soils', *Soil science*, vol. 78, no. 2, p. 154.

Venables, T. 2011. Recycled human urine as a fertiliser for horticultural plants. Thesis for BSci (Hons). College of Health and Science, School of Natural Sciences, The University of Western Sydney

WHO 2006. Guidelines for the safe use of wastewater, excreta and greywater. World Health Organisation.

7 ANALYTICAL STUDIES OF URINE

...there are all these little practical things [in the analytical studies] that have been quite unexpected... I mean, anything that's straightforward or you think is straightforward, is not [in trialling innovation].

Kumi Abeysuriya, Senior Research Consultant, Institute for Sustainable Futures, UTS

In keeping with the project's exploratory intent to open the space for further research and practice, we undertook small-scale analytical studies of urine. The studies were designed to provide indicative local information as a starting point for assessing the nutrient content and enabling comparison with studies elsewhere, as well as to provide data of relevance for public health and safety considerations.

We were therefore interested in

1. The concentrations and forms of key nutrients
2. How concentrations of key nutrients changed during prolonged storage
3. The extent and variability of microbial contamination of urine
4. How prolonged storage affected the extent of microbial contamination (die off)
5. The prevalence of endocrine disrupting/ personal care/pharmaceutical products in urine

Urine samples were collected from waterless urinals located in a male toilet block adjacent to a café in the main university building, and a UD toilet located in the female toilet block serving research staff from two university research facilities (see chapter on *Installation of the UD system*).

To assess the *variability* in nutrients and microbial contamination, fresh urine samples were collected once per week for six weeks during the first half of the day (8 am till 12 pm). Samples were analysed on the same day of collection, hence sampling had to be complete before midday to allow time for delivery to the laboratories. The timing of the collection meant that we frequently struggled to collect sufficient volume[30] of sample urine

[30] We required around 2 litres of urine to fill all the sample bottles to meet the laboratory's testing protocols.

from the female UDT that serviced a relatively small staff population who also had a choice between the UDT and two standard toilets – so the number of females contributing to the sample was small (estimated at around 6-8). Greater volume was collected from the male urinals, but because the time window excluded the peak lunch time at the café, the number of male contributors to the sample was also relatively small (around 15 [31]). To assess how constituents *change over a six month storage period,* 10 litres of urine from each site were collected over a 4-day period, and split into subsamples for analysis at monthly intervals.

The samples were tested for:

- Inorganic plant macronutrients[32]: nitrogen (as total nitrogen; total Kjeldahl nitrogen; ammonium; nitrites; nitrates), phosphorus (as total phosphorus; soluble reactive phosphorus), potassium, calcium and magnesium
- Inorganic plant micronutrients[32]: sodium, boron, zinc, iron, copper and manganese
- Organic matter indicated by chemical oxygen demand (COD)
- Electrical conductivity (EC)
- Presence of bacteria[33] and viruses[34]
- Micropollutants [35] (endocrine disrupting products (EDCs), personal care products (PCPs) and pharmaceuticals): Caffeine, Atenolol, Carbamazepine, Dilantin, Ibuprofen, Naproxen, TCEP, Estrone, Estriol, Ethynylestradiol, Mestranol, b-Estradiol, Trimethoprim, Fluoxetine, 4-acetamidophenol, Ketoprofen, Triclosan, Diclofenac, Atorvastatin, Gemfibrozil.

Figure 37: Urine sample bottles ready for transportation to Sydney Water for analysis

[31] Electronic usage counters on the urinals counted 13 uses during one sampling period.

[32] Macronutrients and micronutrients are the essential elements that plants generally require in relatively larger and smaller amounts respectively.

[33] Using *Escherichia coli* as indicator organism.

[34] Using *Total F-specific bacteriophage* (F-RNA and F-DNA).

[35] Indicated by HPLC-MS/MS negative ESI mode; HPLC-MS/MS positive ESI mode; and HPLC-MS/MS APCI mode

7.1 VARIABILITY OF NUTRIENTS ACROSS SAMPLES

A summary of plant macronutrients and micronutrients measured in the 'fresh' urine is provided in Table 5 and Table 6 below, which show the average amount ± standard deviation[36] of the six samples.

The data from studies elsewhere are shown for comparison (*italicised*). UDT data from Currumbin Ecovillage are presented for comparison with our UDT data. The literature values from European sources for undiluted urine are presented for comparison with our waterless urinal data.

Table 5. Macronutrients in weekly samplings of 'fresh' urine (n=6)

Plant macro nutrients	Nitrogen (Total N) (mg/L)	Phosphorus (Total P) (mg/L)	Potassium (K) (mg/L)	Calcium (Ca) (mg/L)	Magnesium (Mg) (mg/L)
UDT (female urine + flushwater)	**2900 ± 900**	**200 ± 40**	**1000 ± 400**	**40 ± 10**	**30 ± 20**
Measurements from UDTs at Currumbin Ecovillage (male & female urine + flushwater)[37]	*1970 ± 870*	*120 ± 50*	*440 ± 120*	*8 2*	*<0.5*
Waterless urinals (undiluted male urine)	**6500 ± 600**	**300 ± 40**	**1400 ± 500**	**50 ± 20**	**20 ± 10**
Literature values for undiluted urine	*9200[38] 7250-8500[39]*	*740[38] 940-980[39]*	*2200[38]*	*190[38]*	*100[38]*

Table 6. Micronutrients in weekly samplings of 'fresh' urine (n=6)

Plant micro nutrients	Sodium (Na) (mg/L)	Boron (B) (µg/L)	Iron (Fe) (µg/L)	Copper (Cu) (µg/L)	Zinc (Zn) (µg/L)	Manganese (Mn) (µg/L)
UDT (female urine + flushwater)	**1078 ± 564**	**887 ± 133**	**47 ± 16**	**34 ± 40**	**136 ± 71**	**<1**
Measurements from UDTs at Currumbin Ecovillage[37] (male & female urine + flushwater)	557 ± 183					
Waterless urinals (male urine)	**1619 ± 593**	**938 ± 57**	**27 ± 19**	**11 ± 1**	**233 ± 34**	**<1**

[36] Due to the small number of samples (6), standard deviation was calculated using the (n-1) method.
[37] Hood et al. (2008)
[38] Mean values compiled from various sources, in Udert et al. (2006).
[39] Hellstrom, D. and E. Karrman (1996).

In the discussion on the results that follows, it is clear that the variability between samples is significant. There are two features of our experimental context that contributed to this. Firstly, the sampling apparatus for both UDT and waterless urinals was designed to collect a few litres only i.e., an ample volume for the analyses required. To capture 'fresh' urine our simple design was to catch the urine in a short period of sampling time. An unforeseen limit of this design is that the number of contributors to the sample must be small, so all samples lack the levelling effects of collection at scale from a larger population, and are instead very sensitive to the differences between individuals contributing urine to the sample. Secondly, the variable flush volume (i.e., dilution of urine) from the UDTs limits the ability to make meaningful comparisons both within the trial and across other trials, as elucidated further below.

7.1.1.1 Flush water impact on nutrient concentrations derived from UDTs

The level of dilution of urine by flush water in UDTs is difficult to predict because it is determined by not only the technical design for flushing but also user practice. The technical design is variable between UDT models: some admit water into the urine pipe with every half- and full-flush while others do not[40], and the half-flush may discharge a fixed volume of water with each use[41] or it may be determined by how long the flush button is depressed by the user[42]. User practice influences urine dilution in three more ways: whether they activate the flush button or not[43], whether they activate the half- or full-flush button, and how much urine they excrete at each use the toilet. During urine sampling from our Dubbletten UDT, we erected signage in the toilet cubicle requesting users to avoid unnecessarily rinsing the urine bowl. It was not possible to monitor dilution by rinse water more closely within the scope of the project, so dilution of samples could range from nil to around 100% (1:1)[44]. When dealing with large volumes of urine, estimates of averages for each of the fractions in the mixture can be meaningful. But when collecting small volumes with different individuals contributing to the samples, as was the case in our trial, predictions based on 'average' behaviours become less meaningful. Thus in comparing UDT data within the trial and across trials conducted by others, the variable dilution impacts of flush water on nutrient concentrations need to be acknowledged.

[40] The two UDTs used in our trial demonstrated each of these design options (see chapter on *Installation of the UDTs*). The Dubbletten UDT flushed only the rear toilet bowl, and had a separate button to activate rinsing for the urine bowl if required.

[41] Hood et al (2008) describe the Gustavberg UDT used in the Currumbin Ecovillage trial as adding fixed volumes of 200 ml and 400 ml respectively to the urine tank with each half- and full-flush, and combined with the use of flush counters, enabled the amount of flush water in their urine tank to be calculated.

[42] Our Wostman model belonged to this latter class of UDT, with a half-flush that discharged around 250 ml into the urine pipe with a 'typical' 1 second press of the flush button, but could discharge as much as 475 ml (corresponding to the full-flush).

[43] Water-conscious users might observe the Australian ditty to conserve water: "if it's yellow, let it mellow; if it's brown, flush it down!" (especially male users who use no toilet paper) thus reducing dilution.

[44] A 'long' urine bowl rinse of 4 seconds we estimate could add around 290-300 ml of water, in comparison with excreted urine volumes of the order of 250 ml per use.

7.1.1.2 Variability of nutrients observed across samples at UTS

The concentrations of most nutrients varied greatly between samples from the UDTs and the waterless urinals, as indicated by the relatively large standard deviations in the graphical representations in Figure 38 below (20% of the mean or more in most cases). The variation is unsurprising for the reasons discussed above. That said, the variation is no worse than that reported in the literature, as the above tables show.

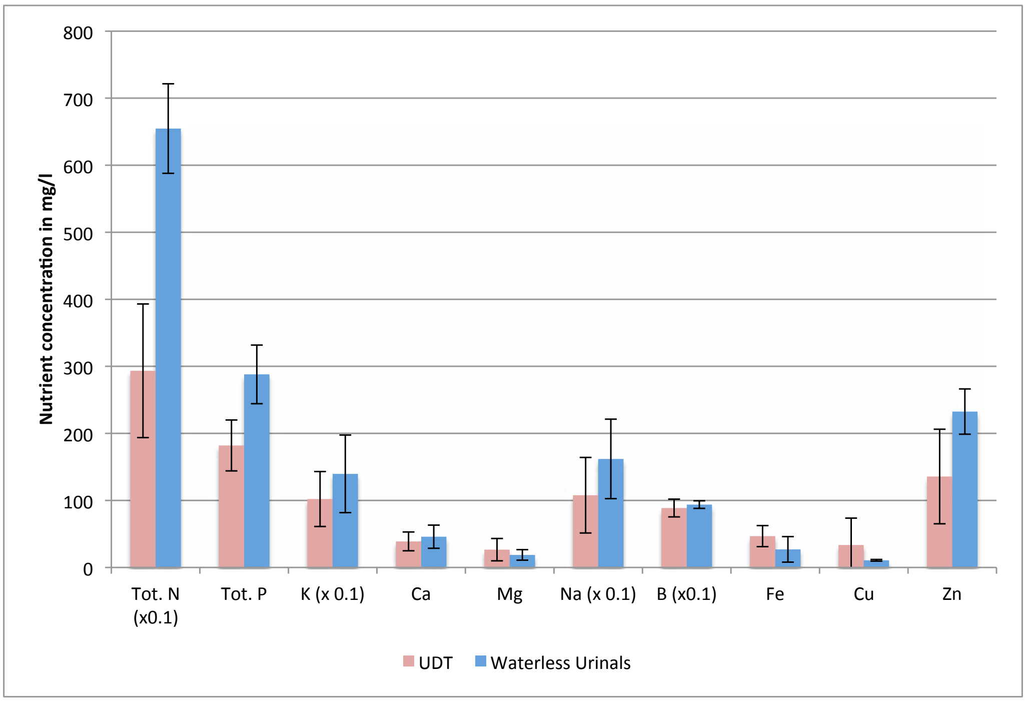


Figure 38: Means and standard deviations for nutrient concentrations in UTS samples from UDT and waterless urinals[45]

There are significant and variable differences between our data from the UDTs and the waterless urinals. As shown in Figure 38, concentrations from the urinals are greater than from the UDTs for the abundant nutrients, but intriguingly reversed for some of the less abundant nutrients. While flush water is one contributing factor, the changing relativities indicate that other factors are at play. For example, there may be significance in input differences i.e., urine characterised by gender and dietary differences[46].

The difference is highest for N, with Total Nitrogen from the urinals roughly double the value from the UDTs. In addition to the possible impact of dilution, nitrogen in urine is strongly influenced by time of day, diet and exercise (Vinneras 2011). Hellstrom and Karrman (1996) observed that total nitrogen and phosphorus in male urine was greater than in female urine. Phosphorus in urine is related to body weight, and Hellstrom and Karrman (ibid.) suggest that lower average female body weight may be a factor in the phosphorus result. Jönsson et al. (1997) note that vegetarian diets contain less nitrogen

[45] This is a graphical representation of the data in Tables 5 and 6, with the most abundant elements N, K, Na and B scaled by factor of 10 to display relativities on same graph.

[46] Dietary supplementation could, for example, explain the high Fe in the female UDT samples.

and phosphorus on average, and the unusually high prevalence of vegetarianism amongst the users of our UDTs[47] could be another contributing factor.

Boron concentrations (Figure 38) were quite intriguing, for showing little difference between concentrations from the waterless urinals (undiluted urine) and the UDT (variable dilution), and furthermore, for showing very low variation between samples – with standard deviations of just 6% of the mean for the waterless urine, and 15% for the UDT samples[48].

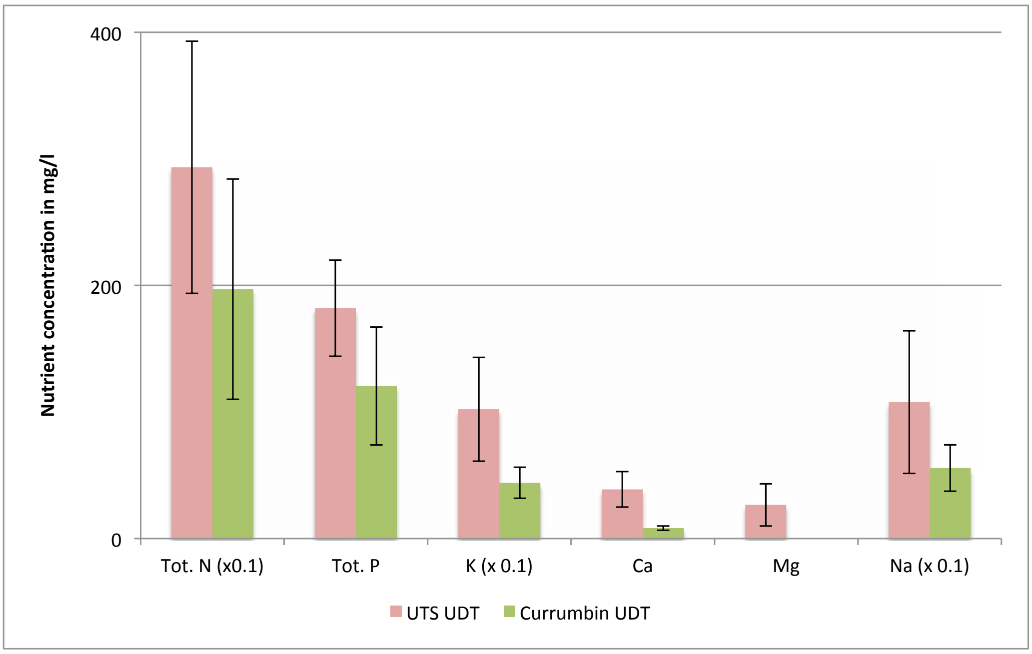


Figure 39: Nutrient concentrations from UDTs at UTS compared with Currumbin Ecovillage[45]

The large variations in nutrient concentrations between samples from the UDT mirror the large variations seen in the data[49] from Currumbin Ecovillage (Figure 39 and Table 5). The UTS measurements are significantly and consistently higher than Currumbin measurements. Differences in flush water would contribute in several ways. Firstly, the dilution by flush water may have been greater at Currumbin, where Hood et al. (2008) note the addition of 200 or 400 ml of flush water with every half or full flush, whereas rinse water additions at UTS ranged from nil to about 250 ml with some users possibly responding to the signage requesting minimal rinsing of the urine bowl. Secondly, the recycled water supply[50] for flush water at Currumbin Ecovillage potentially has a very different mineral profile to Sydney tap water supply at UTS – for example, very low levels of Ca and Mg at Currumbin (Table 5). Another possibility is the effects arising from different hardware configurations i.e., different pipe materials (copper, PVC, cast iron, etc.) and ages for flush water supplies and collection systems.

---

[47] Many staff at the Institute for Sustainable Futures are vegetarians in line with their commitments to sustainability, since meat diets have a significantly larger ecological footprint.

[48] The effect of laboratory methods for determining B levels may be an avenue for further investigation.

[49] Currumbin Ecovillage samples were from the urine tank of one household (Hood et al. 2008).

[50] Currumbin Ecovillage is off the urban water grid and uses rain water for potable supply, and recycled water for toilet flushing (Beal et al. 2008).

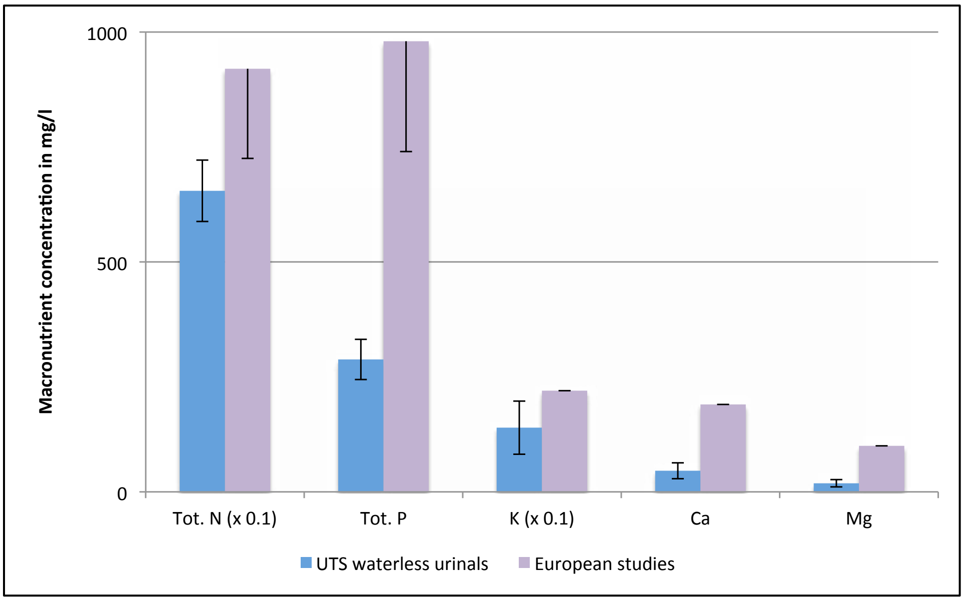


Figure 40: Nutrient concentrations in undiluted urine from UTS and literature[45]

The urine nutrient data from our waterless urinals are the first Australian published results for undiluted urine. Figure 40 and Table 5 show the average concentrations of macronutrients at UTS were significantly lower than the values published by European authors – phosphorus concentrations at UTS were around one-third of those reported elsewhere. This scale of difference is surprising. Potential explanations include differences in the diets and lifestyles of the sampled population groups, and sampling and analytical protocols.

7.1.1.3 Electrical conductivity and Chemical Oxygen Demand

Electrical Conductivity (EC) and Chemical Oxygen Demand (COD) (Table 7) show relatively low variation between samples from the UDT and waterless urinals, indicated by low standard deviations relative to the mean values (<15%). Across trials, they show a similar pattern of variation as seen with nutrients – EC and COD are higher in male urinal samples than female UDT samples at UTS; EC from UTS UDTs are higher than from Currumbin Ecovillage UDTs; and COD measured in undiluted urine at UTS were much lower than in European studies.

Table 7: EC and COD in weekly samplings of 'fresh' urine (n=6)

	Electrical Conductivity (mS/m)	COD (mg/L)
UDT (female urine + flushwater)	**1800 ± 200**	**4000 ± 600**
Measurements from UDTs at Currumbin Ecovillage (male+female urine + flushwater)	*1300 ± 470*	
Waterless urinals (undiluted male urine)	**3550 ± 200**	**5800 ± 500**
Literature values for undiluted urine		*10,000*[38]

7.2 CHANGE OF NUTRIENT FORMS OVER 6 MONTHS STORAGE

The major N-P-K macronutrients remained stable during storage. Total nitrogen and ammonia nitrogen showed no significant variation (just 2-3%) in concentration between samples analysed at monthly intervals over the six months. This is consistent with Udert et al. (2006) and Jönsson et al. (1997) who show that urea in fresh urine is rapidly dissociated to ammonium forms with little further dissociation during enclosed storage. Total phosphorus was also relatively stable with a 23% variation in the UDT samples and 6% variation in the waterless urinal samples. Potassium measurements had a 8% variation in both urinal and UDT data. These stabilities are consistent with Udert et al.'s and Jönsson et al.'s results for phosphorus and potassium levels during storage.

The remaining macronutrients calcium and magnesium showed much greater variation. In the UDT data, there was no clear trend evident, showing variations of 40% and 80% for Ca and Mg respectively across the measurements. For the waterless urinal data, an initial drop between Month 0 and Month 1 is evident for both nutrients, after which there is some variation with no clear trend. This is consistent with Udert et al (2006) who have Ca and Mg concentrations reducing to zero in their simulated stored values (most likely taking account of precipitation).

The micronutrients sodium and boron are stable in storage, showing low variations of between 7% and 12% across the samples for both urinal and UDT data. There is much greater variation in the other measured micronutrients but no clear trend is evident.

7.3 MICROBIAL PRESENCE IN URINE SAMPLES

The presence of microbial pathogens is important for health and safety concerns in the storage, transport and direct use of urine as a fertilizer. World Health Organisation guidelines for urine reuse (WHO 2006) note that faecal cross-contamination in a urine diverting toilet is the most significant health risk. Studies elsewhere (Schönning &

Stenström 2004) show that indicator bacteria and protozoa in concentrated urine show rapid die-off in temperatures of around 20°C (a day or less), while indicator viruses are more persistent but are inactivated over longer storage periods. Higher dilutions and lower temperatures result in longer survival times, but indicator bacteria die off after a month at 4°C in dilutions up to 1:9. The studies indicate that 6 months storage in Sydney temperatures[51] would inactivate all pathogens in the urine mixture (WHO 2006, Schönning & Stenström 2004).

We wanted to repeat these studies locally, using a NATA registered lab[52], to help give regulators confidence in international experiences. Through discussions with local regulators and analytical specialists, we chose *E. Coli* as an indicator organism for faecal contamination, although Schönning and Stenström (2004) note that its rapid die-off in the urine environment does not mimic the die-off of different bacterial pathogens.

We encountered several unexpected issues that dramatically impacted what results we were able to get. The NATA registered laboratory had a great deal of difficulty with this analysis. They reported a high degree of background interference with the 'fresh' weekly samples that prevented accurate enumeration of indicator organisms. The labs reported phage results (<10 pfu/100ml) for both UDT and urinal samples with the qualifier "best detection possible due to matrix interference" with 25-30% recovery in spiked samples, and "host failure on positive samples", and recommended that microbial analyses on 'fresh' samples be discontinued following the second week of sampling. The monthly analysis on sub-samples in the six-month storage study still experienced matrix interference and low recovery of the phage studies for all results from both UDT and waterless urinals. The *E. Coli* results showed the expected deactivation in the six-month storage study, reducing from *<10 CFU/100ml* at the beginning to detectable limits after the first month

As a certified lab for the water sector (see Acknowledgements section), the lab was unfamiliar with urine analysis. Crystalline precipitates[53] were present in all collected samples, and sampling protocols did not require filtration, and it is unclear whether particulates were equally distributed amongst subsamples. The precipitates agglomerated over time and were a suspect for the matrix interference in the phage analyses, giving very poor recoveries of spiked control species. This is consistent with international experience (Vinnerås pers. comm.), where filtration of samples before spiking is conducted for improving recovery rates of phage. It was therefore surprising when results from filtration did not improve recovery to any significant degree.

The second source of the difficulty is likely to have been contamination of urine as a result of our sampling set-up. The lab results on 'fresh' urine (before this test was discontinued) showed unusually high *E. Coli* levels consistent with contamination in both UDT and waterless urinal samples, at ~4800 and 700 CFU/100ml respectively. While some faecal

[51] The Australian Bureau of Meteorology reports average temperatures in the Sydney region as ranging around 10-23°C in recent years.
[52] Laboratory accredited by National Association of Testing Authorities, Australia (NATA) for conducting specified tests.
[53] We attributed the particulates to early struvite formation from the pipework, but did not confirm this through analysis.

contamination can be expected in UDT samples, the key suspect in the high levels of contamination including the samples from waterless urinals is the odour trap installed in the pipework (see chapter on *Installation of the UD system*). The trap was a likely breeding site for organisms, and urine samples could have picked up extra organisms as it passed through the trap. If we had to repeat the trial, we would eliminate such a trap, and ensure that samples for analysis would bypass any potential breeding sites. We would also replace the corrugated flexible hose at the bottom (installed for easy filling of collection vessels, see Figure 41 right) with a smooth flexible hose.

We discuss potential improvements to a sampling set up in *Appendix 1* (*Practical pointers for installing UDTs and waterless urinals*) based on our learning from our failures.

Figure 41: Urine sampling set up for UDT (left), and sample collection from the waterless urinals (right)

7.4 OCCURRENCE OF MICROPOLLUTANTS

Consultations with our partner from the NSW Health Department about concerns regarding urine reuse revealed that the range of micropolluting and endocrine disrupting substances found in pharmaceuticals, personal care products and other chemical products are an issue of significant current concern. Winker (2009) states that micropollutants are also very complicated to measure as they include a very large number of substances that vary in terms of their effects on plants and soil and other life forms, and vary in how they are affected by storage - some substances decay, while others remain unchanged after very long periods. *"Hence, it has to be concluded that pharmaceutical residues are present in urine after storage and have to be kept in mind when it comes to reuse in agriculture"* (Winker 2010).

The water sector lab conducting our analyses (see Acknowledgements section) routinely tests for a particular suite of micropolluting substances in their standard testing routines for the water sector, and included these 20 substances in our urine sample analyses.

Micropollutants in urine are much more personalised than nutrients, since many nutrients are consistently present in urine whereas the consumption of pharmaceuticals and personal care products are more personal. As could be expected from small volumes of urine collected from a variable small population, the presence and concentrations of the substances detected varied considerably. In Table 8 below we report the substances that were present at levels above the detection limit. The detected pharmaceutical products reflect the range of conditions that might be present amongst a university population as noted within the Substance column in Table 8.

The storage study included 3 measurements only, at the beginning, after 1 month, and after 6 months. We have attempted to draw preliminary and indicative conclusions where the samples from the UDTs and the waterless urinals both showed the same trend over the storage period. The very limited extent of the testing means these conclusions on the possible effect of storage should be considered indicative only, for further verification if relevant to public health.

Table 8: Micropollutants detected in the urine analysis in the UTS trial

Substance	Presence in UDT samples (female urine + flushwater)	Presence in waterless urinal samples (male urine)	Possible effect of storage (concentration relative to Month 0 at start of storage period)
Caffeine	Present	Present	Slow decay (100% at Month 1, 50% at Month 6)
Carbamazepine (Anticonvulsant, for nerve pain/ epilepsy/ bipolar)	Not present	Present	Stable
Ibuprofen (Analgesic anti-inflamatory)	Present	Present	Inconclusive
Naproxen (Analgesic anti-inflamatory)	Present	Not present	Inconclusive
Estrone, Estriol (Estrogen types)	Present	Not present	Inconclusive
Fluoxetine (Antidepressant)	Not present	Present	Inconclusive
4-acetamidophenol	Present	Present	Rapid decay

(Analgesic antipyretic)			(25% or less at Month 1, ~ 1% at Month 6)
Triclosan (Anti-bacterial anti-fungal)	Present	Present	Inconclusive
Diclofenac (Anti-inflamatory)	Present	Present	Inconclusive
Atorvastatin (Cholesterol reducing)	Not present	Present	Inconclusive
Gemfibrozil (Cholesterol reducing)	Not present	Present	Inconclusive

ACKNOWLEDGEMENTS

We are grateful for the considerable expertise of Sydney Water staff for their valuable research partner contribution of the laboratory analyses, provided through the services of their NATA accredited laboratories. In particular, we sincerely thank *Dr Mark Angles* (Water Quality & Public Health) for his advice on experimental design, sampling, and interpretation, and *Ms Elsa Miguel Barrett* (Technical Specialist) for managing the analyses.

We also thank our international colleagues *Dr Björn Vinnerås* (Swedish University of Agricultural Sciences, Sweden) and *Dr Tove Larsen* (EAWAG, Switzerland) for their expert advice and assistance in interpreting our results.

PERSONAL COMMUNICATIONS

Larsen, Tove. Personal communication. 9 November 2011

Vinnerås, Björn. Personal communication. 8 December 2011

REFERENCES

Beal, C., Gardner, T., Ahmed, W., Walton, C. and Hamlyn-Harris, D. (2008). 'Closing the nutrient loop: a urine-separation and reuse trial in the Currumbin Ecovillage, Queensland'. Onsite'07 Conference Proceedings, Armidale 2008.

Hellstrom, D. and E. Karrman (1996). 'Nitrogen and phosphorus in fresh and stored urine'. Recycling the Resource: Second International Conference on Ecological Engineering for Wastewater Treatment, School of Engineering Wadenswil, Zurich, Transtec Publications.

Hood, B., Gardner, T., and Beal, C. (2008). Domestic urine separation is effective in capturing plant macronutrients, nitrogen, phosphorus and potassium. Onsite and Decentralised Sewerage and Recycling Conference 'Coming Clean: Sustainable Backyards and Beyond!', Benalla, Victoria, Australia, Australian Water Association.

Jönsson, H, Stintzing, A, Vinnerås, B, & Salomon, E 2004, Guidelines on the use of urine and faeces in crop production, EcoSanRes Programme and the Stockholm Environment Institute.

Jönsson, H., Stenström, T.-A., Svensson, J and Sundin, A. (1997), 'Source separated urine-nutrient and heavy metal content, water saving and faecal contamination'. Water Science & Technology 35 (9): 145-152.

Winker, Martina. 2009. "Pharmaceutical residues in urine and potential risks related to usage as fertiliser in agriculture." In AWW Institut fur Abwasserwirtschaft und Gewasserschutz: Hamburg University of Technology (TUHH)

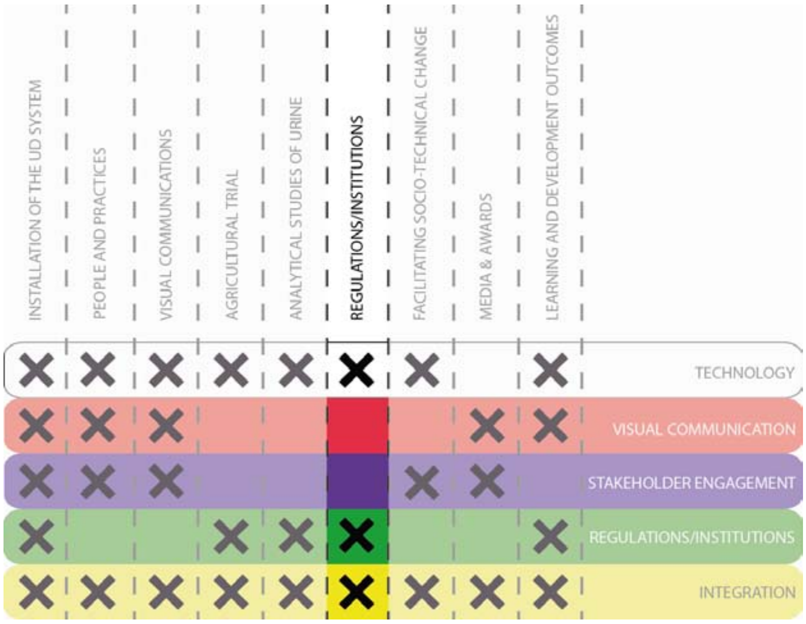
Udert, K. M., T. A. Larsen and W. Gujer (2006). "Fate of major compounds in source-separated urine." Water Science & Technology 54 (11-12): 413-420.

Schönning, C. and T. A. Stenström. 2004. "Guidelines of the safe use of urine and faeces in ecological sanitation systems." EcoSanRes, Stockholm Environment Institute, Swedish department for infectious diseases. .

Schönning, Caroline. 2001. "Urine diversion – hygienic risks and microbial guidelines for reuse." Swedish Institute for Infectious Disease Control, Stockholm, Sweden

WHO. 2006. *Guidelines for the safe use of wastewater, excreta and greywater. Volume 4 Excreta and greywater use in agriculture*. World Health Organisation.

8 REGULATIONS AND INSTITUTIONS



'The most significant learning experience for me was understanding the way waste can be recycled for community and social benefit…and through meeting others in the team, I've learned to appreciate the complex technical issues related to installing new innovation and the gap that exists between good ideas and supporting policy'.

Janice Gray, Law Department, University of New South Wales

The aim of the Regulations and Institutions research strand was to investigate the relevant regulations, policies, guidelines, standards and processes for urine diversion and reuse at the national, state, local government levels and at institutional level (e.g. participating university). Regulations and institutions determine what is permissible and feasible, and were necessary to explore as part of the project, firstly to enable the UTS Sustainable Sanitation Project to be compliant and legitimate, and secondly to illuminate their role as barriers or enablers of urine diversion at scale.

With an appreciation that regulations exist to minimise risk to the public arising from activities that could have impacts on public health, the environment and the economy etc., we set out to uncover:

a) the range of *regulations* triggered for the different elements of the project's toilet-to-reuse path for urine; how to comply; and to assess whether these controls are appropriate, whether they enable or discourage UD, and how barriers might be overcome without violating their protective intent;
b) *institutional issues* (University procedures) relevant to the elements of the project; and
c) implications for urine diversion in commercial buildings at scale beyond the project.

As the scope of the project evolved and changed in response to early learning (see chapter on *Installation of the UD system*), the hardware trial was limited to the pilot installation of two urine diverting toilets and two waterless urinals with associated sampling and storage systems, and the agricultural reuse trial limited to glasshouse pot trials. The areas that the Regulations and Institutions research strand focussed on changed accordingly, and are represented in the Figure 42 below.

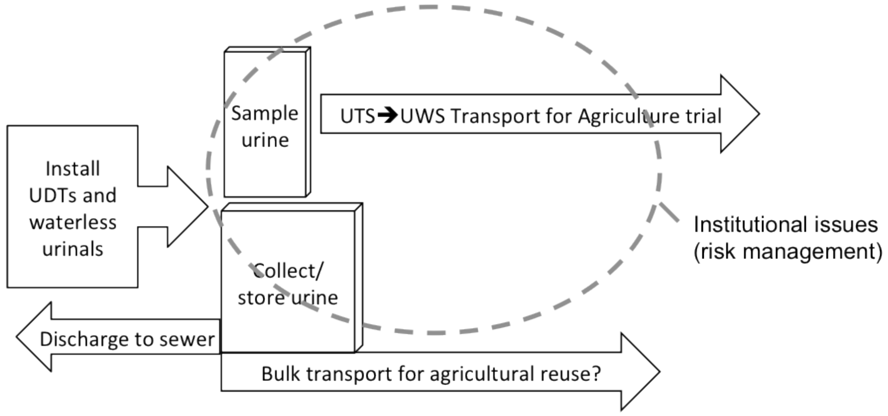


Figure 42: Main areas of focus for the Regulations and Institutions research strand

8.1 INSTALLING UD TOILETS: COMPLYING WITH STATE PLUMBING REGULATIONS

The National Plumbing Code permits only WaterMark certified products to be installed[54]. As no urine diverting toilets are currently certified in Australia, the two models of imported Swedish toilets, *Wostman Ecology* and *Dubbletten,* were tested against the 'Australian Standard AS 1172.1 – 2005 Water Closets' (see chapter on *Installation of the UD system*). Following the testing, the plumbing regulator (see Acknowledgements) made several recommendations for modifications to the manufacturers' installation instructions to allow compliance with the intent of the Plumbing Code[55].

The project team made an application to the Department of Fair Trading (the regulator of plumbing products and drainage in New South Wales) to install the non-certified UDTs, and obtained 'Performance Based Approval' by demonstrating that performance of the installation adequately addressed regulators' concerns about potential risk to public health (see *Appendix 2*).

The Australian-manufactured Caroma *H2Zero* waterless urinals used in the UTS trial are WaterMark–certified and have been on the Australian market since 2007, so they were installed according to manufacturer's instructions without further investigation.

[54] Watermark certified products comply with present regulatory positions and meet required specifications and standards. Certifiers approved by Standards Australia provide licences to applicants following independent assessment and testing, and conduct ongoing monitoring of production processes/quality systems and sample products.

[55] The main recommendations were (a) install an external water seal for the Wostman model to ensure a robust odour seal in high-rise buildings where the sudden pressure variations that can occur would break a weak water seal, and (b) install a back-flow prevention device to the Dubbletten model's urinal flush water flow inlet, to prevent backflow into the water supply in the event of a major blockage in the toilet bowl.

Figure 43: UDT performance being tested on NATA laboratory test rig.

8.2 DISCHARGING URINE TO SEWER

Our planning at the outset needed to cover the full lifecycle of the project, so we also considered the requirements for decommissioning the trial at the end of the project, including emptying the tank to sewer. We sought advice from Sydney Water about whether a trade waste licence was required for discharging a large quantity of urine when tanks were being emptied for decommissioning or cleaning in a longer term installation. We were advised that for the scale of our project a licence was not required. However, it was identified as a potential issue to be addressed in the case of larger volumes and/or more widespread instances of urine collection and storage.

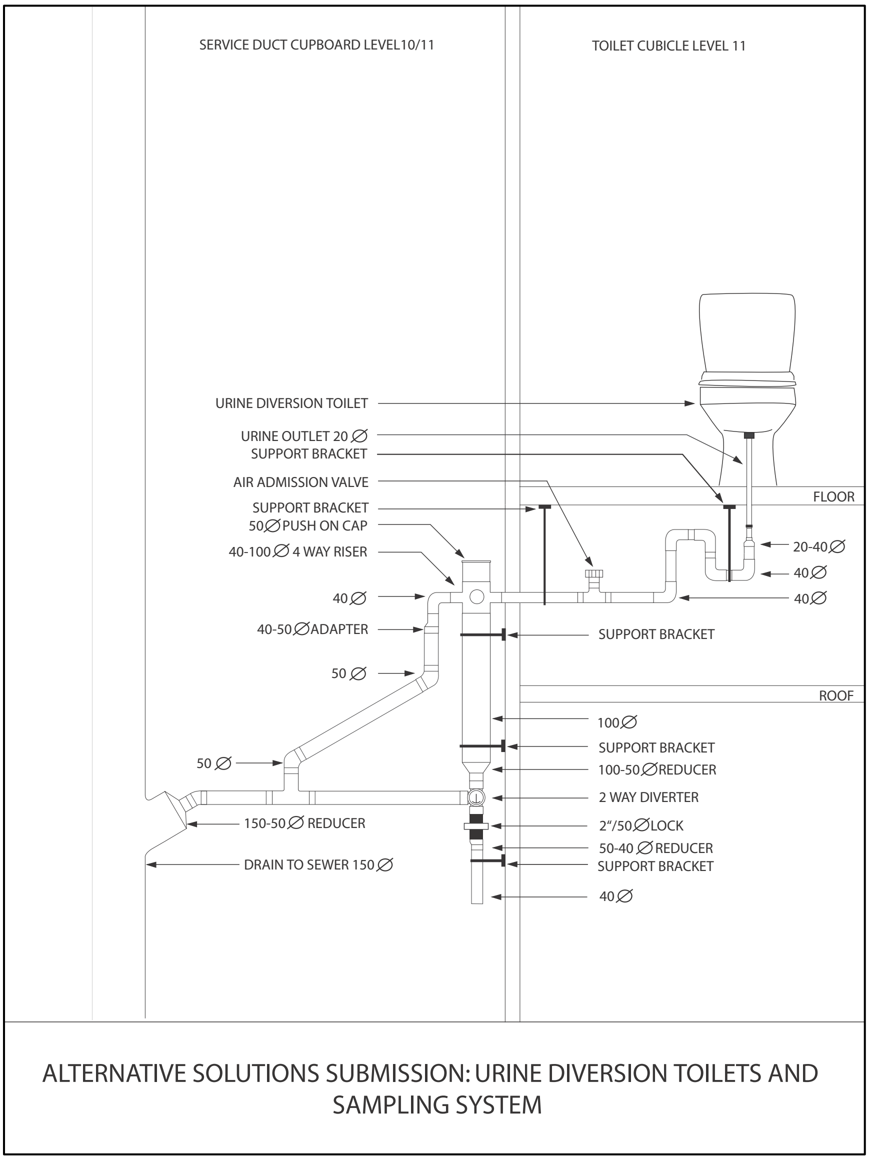


Figure 44: Technical drawing submitted with application for Performance Based Compliance (see Appendix 2 for full application)

8.3 URINE STORAGE AND HANDLING: ADDRESSING UNIVERSITY REQUIREMENTS

At both UTS and UWS, relevant institutional authorities displayed a strong perception of high risk associated with potential human interaction with urine that we needed to respect. There were four places of interaction identified: collection of urine samples at UTS (from UDT in Building 10 and waterless urinals in Building 1); storing urine in a tank in the basement car park at UTS (Building 1); transporting urine from UTS to UWS; and handling urine in the agricultural pot trial at UWS.

We prepared two separate risk management plans for the sampling and the tank storage at UTS. This was not definitively required for UTS Bioethics compliance, but we wanted to be proactive so that we would be ready to respond to any concerns of the local institutional authorities.

- For urine sampling, the plan included steps to avoid accidents and injury (e.g., labelling of 'open'/'closed' positions of diversion valves, and supports to avoid lifting heavy containers), preparation for accidents (e.g., providing access to disinfectant and implements for cleaning up spills), and minimising exposure to pathogens (e.g., washing procedures, wearing suitable protective clothing). Although not included in the plan, samples sent by courier to Sydney Water laboratories for analysis followed procedures that aligned with Australian Standard AS 4834-2007 'Packaging for surface transport of biological material that may cause disease in humans, animals and plants'.
- The risk management plan for the storage tank included all of the above and additional measures to avoid vandalism and accidental impacts in the car park (e.g., placement of tank in a locked mesh cage), to avoid spills and overflows (e.g., including fail-safe measures in the pipework), to be prepared for accidental puncturing of tank (e.g., installation of spill containment bund of sufficient capacity to hold full contents of tank), and to monitor and manage nuisance effects on other users (e.g., odour and noise).

Bioethics approval was obtained from the Biological and Radiation Safety Committee at UWS for handling urine for the experimental pot plant application. The committee required that the urine from UTS be packed, labelled with appropriate bio-hazard warnings and transported to UWS in accordance with Australian Standard AS 4834-2007 'Packaging for surface transport of biological material that may cause disease in humans, animals and plants'[56]. Appropriate procedures for application of the urine to the potting mix in the experiments were also developed to minimise inhalation of droplets and other potential exposure paths.

In undertaking an innovative project like this, it is worth noting that the nature of the risks that need to be managed extends beyond the technical domain to institutional and political domains. Whilst we had worked hard to engage a diverse range of local stakeholders, the process of locating the urine storage tank demonstrated that we had not gone far enough. The strong perceptions of high risk that we experienced from the formal University risk management processes should have been a trigger for us to realise that the idea of locating a urine storage tank in a public, multi-use space[57] would need to be delicately handled. Whilst the process did experience some hurdles, and the project did cause some unintended consternation, all was resolved once negotiations were transferred to the appropriate level, between more senior members of staff. The key lesson was the need to identify all the parties affected by each element of the project, to identify the relationships between the parties, to map out the full range of potential responses, and plan accordingly, ensuring each element of the project includes the strategic stakeholders in those negotiations. In the case of the placement of the urine sampling apparatus in Building 10, in a locked service duct cupboard within a toilet block, this principle required

[56] The biochemical analysis carried out after two months of storage prior to transportation for the agricultural trial (see *Agricultural Trial* chapter) showed undetectable microbial presence in the urine, which did not relieve the Committee's perceptions of the risk of this human waste product.
[57] The basement had a wide variety of uses, including car parking for senior University staff and significant visitors, storage space for the media and communications division, delivery areas, workshops for science and engineering faculties, and office space for operational facilities management staff.

discussion with the Building Manager and Facilities Management staff who were already part of our extended project team.

RISK MANAGEMENT MATRIX FOR INSTALLATION/OPERATION/DECOMMISSSION OF URINE COLLECTION FROM WATERLESS URINAL TRIAL

	ACTIVITY	INHERENT RISKS/HAZARDS	CONTROL MEASURES	RESIDUAL RISK MEASUREMENT
INSTALLATION	**Manage expectations of neighbours on Level 2 & 3**	• **Reputational risk**	• Identify and manage stakeholder engagement with actors directly involved with the installation site - Level 2 and level 3, building 1 (Science workshop, Central Services, Equity Diversity Unit) • Seek stakeholder input into the installation process	• Likelihood of harm is LIKELY • Consequence of harm is MINOR **MEDIUM RISK**
	Manage odour prevention	• **Complaints from neighbours**	• Plan weekly site inspections • Engage weekly with neighbours in regard to gaining their perceptions of odour on-site	• Likelihood of harm is LIKELY • Consequence of harm is MINOR **MEDIUM RISK**
	Manage capacity of urine tank	• **Overflow of urine tank**	• Installation of Saniflow pumping mechanism with connection and overflow to the sewer set to trigger overflow at 500L of collection • Installation of a two-way diverter to divert urine to sewer when required • Weekly inspections to track urine collection level	• Likelihood of harm is LIKELY • Consequence of harm is MINOR **MEDIUM RISK**
	Manage interference of urine tank during collection process	• **Unexpected impact of tank from vehicles in car park**	• Install locked wire cage 0.5m around collection tank to provide buffer and absorb impact from unexpected vehicle collision	• Likelihood of harm is POSSIBLE • Consequence of harm is MODERATE **MEDIUM RISK**
		• **Tampering of tank/fittings by unauthorised personnel**	• Install locked wire cage to the height of 7ft around collection tank to limit access by unauthorised personnel	• Likelihood of harm is POSSIBLE • Consequence of harm is MODERATE **MEDIUM RISK**
		• **Vandalism**	• Engage with Security (FMO) to monitor installation site for potential vandalism • Limit access to collection tank by installing locked wire cage	• Likelihood of harm is POSSIBLE • Consequence of harm is MODERATE **MEDIUM RISK**

Page 1 of 4

Figure 45: A page from the Risk Management Plan for the urine storage tank (see *Appendix 3* for full plan)

8.4 BULK TRANSPORT OF URINE

As we envisioned a larger land-based agricultural trial at the beginning of the project, we sought advice from the NSW Department of Environment, Climate Change and Water regarding licensing for transportation of 1000 L tanks of urine from the CBD (UTS) site to peri-urban Sydney (UWS). The advice was that urine collected from the university population (assumed healthy) would not require any licencing under the Protection of The Environment Operation Act 1997.

The question of bulk transport was further explored for the research assignment of a Coursework Masters in Environmental Law from Macquarie University (see Acknowledgements). It made the following findings:

- Urine collected from populations having no known risk of carrying infectious agents, is not a "special waste" requiring licencing or waste tracking [58].

[58] Urine collected from a medical or aged-care facility must follow the 'Transport of Dangerous Goods Code' and the 'Hazardous Substance and Dangerous Goods in NSW Health – Guidelines for Safe Use (July 2006)'

- The transport of urine can be deemed unlawful if the reuse application ('depositing of waste') has not been approved by the Office of Environment and Heritage. In this case the *transporter* can be penalised.
- Urine meets the definition of a fertilizer[59] so land application could potentially be regulated under the Fertilizers Act, although this is yet to be tested and confirmed.
- Local government retains general power to regulate the transport of urine (for example the route and time of transport), and potentially collection, storage, treatment of urine. The framework for regulation by local government is, however, not explicit.

8.5 SUMMARY AND NEXT STEPS

Urine diversion and reuse is not specifically accommodated within the current regulatory landscape. Furthermore, urine diversion will continue to be a low priority for regulators unless the sector develops further and creates the need for regulation. In order to enable just such sector development, it would be beneficial to develop guidelines based on research and experience in the field[60] that can be used to support more projects to be implemented, with the growing experience being used to refine and improve the guidelines in an iterative process. Such guidance is needed in relation to the three main activities: urine collection and storage; urine transport; and urine reuse.

8.5.1.1 Urine collection and storage systems

Urban multi-storey buildings need to play a significant role in urine diversion and reuse at scale. With our collaborators and extended peer network from the building sector, we took the first steps towards developing guidelines for urine pipework in multistorey buildings (see *Appendix 1*). The provision of urine pipework in the new UTS Faculty of Engineering and Information Technology will provide the opportunity for practice-based learning so that researchers and building managers can further develop detailed guidelines.

Broader guidance to support the requirements for obtaining site-specific approval from industry regulators for installations that meet appropriate performance based outcomes could include:

- installing UD products that have no WaterMark certification
- installing sanitary plumbing that does not comply with current plumbing regulations

We have prepared an Appendix entitled "*Practical pointers for installing UDTs and Waterless Urinals*" that provides a summary of the learnings most relevant to a plumbing and building industry audience. Our application for Performance Based Installation of UDTs, and our risk management strategies are also included as Appendices to provide a useful starting point for others implementing UD projects in institutional contexts.

---

[59] "[A] substance that contains nitrogen, phosphorus or potassium and is a nutrient supply for enhancing vegetation" (The Fertilizer Act 1985 (NSW)). Exclusions from the definition include septic tank sludge and crude night soil, and biosolids.

[60] Resources such as Sydney Water's 'Waterless Urinals Factsheet' and the National Plumbing Supply Forum's 'Advisory Note' for waterless urinals are good examples.

8.5.1.2 Urine transport

Interpretations of the possible range of classifications for urine for bulk transporters have not been tested, creating a degree of legal uncertainty. Further evidence that can help to legally clarify urine as a fertilizer when collected from healthy populations, will provide legal certainty and minimise risk for the transport industry which is held legislatively responsible for the 'depositing of waste'.

8.5.1.3 Urine reuse at scale

Our health regulator's perspective was that microbial risk associated with urine reuse was of little concern if re-used in accordance with WHO Guidelines,[61] but that there was a concern about the potential risks from the diverse range of endocrine disrupting substances such as some pharmaceuticals and personal care products that can be present in urine. Until such risks are better understood and mitigated, the project concluded that urine reuse be limited to non-edible crops such as turf, ornamentals and silviculture. Further practice-based research on the feasibility and market potential for urine reuse in this crop sector is therefore a high priority for the next phases of research.

It was noted that urine reuse on land (rather than containers or pots, as in the agricultural trial in our project) would require management of environmental risks to groundwater contamination and potential nutrient run-off as a dispersed pollution source, and require environmental regulatory approvals. Understanding these needs to be part of the next phase of research.

ACKNOWLEDGEMENTS

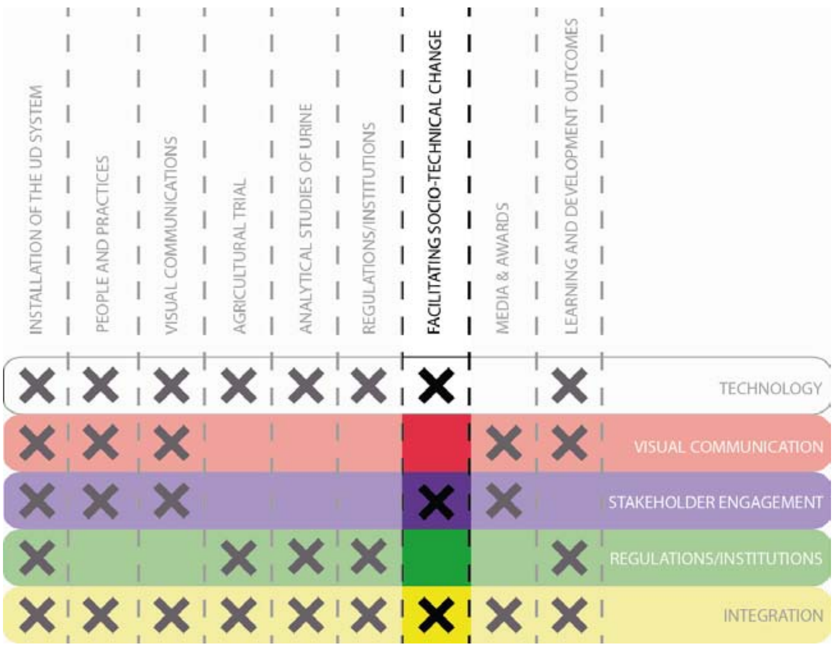
We sincerely thank the following individuals/organisations for their valuable contributions to the research reported in this chapter.

- *Les Barnard* (National Plumbing Regulators Forum) whose considerable expertise and enthusiasm provided excellent guidance for installing the UD toilets, and making an application for 'performance based approval' for the installation and plumbing;
- *Luke di Michiel, Stephen Cummings and associates at GWA Group Ltd* who conducted the NATA-accredited[62] tests on the UD toilets and compared performance against the Australian Standard for water closets;
- *Victoria Burston* (Macquarie University Masters student in Environmental Law, and a collaborator from Sydney Water), who chose her dissertation topic as 'The regulation surrounding the bulk transport of urine destined for reuse on agriculture';
- *Janice Gray* (UNSW Law Faculty) who provided external research supervision of Victoria Burston's research; and
- *Kaye Power* (NSW Department of Health) who provided helpful advice on potential issues.

[61] WHO. 2006. *Guidelines for the safe use of wastewater, excreta and greywater. Volume 4 Excreta and greywater use in agriculture*. World Health Organisation

[62] The National Association of Testing Authorities, Australia (NATA) provides accreditation to laboratories meeting required standards for reliability of test results.

9 FACILITATING SOCIO-TECHNICAL CHANGE



...I came into the project with knowledge in one area. But it was great being able to share that with - and get input from others, be it the regulation side with Les, the plumbing side with David and even from the cleaner's point of view. I think that worked really well in the trial and I gained a lot from it. It was a holistic approach we had with the team [in trialling UD]. Every area was covered.

Luke Di Michiel, Market Segment Manager at Caroma Dorf (toilet and bathroom manufacturer)

The design of the UTS trial was guided by 'Transition Management (TM)', a field of research that seeks to steer transitions towards sustainability. TM highlights the value of experiments as a site for learning about the potential of innovation and facilitating transitions toward sustainability (Loorbach 2010). As this report indicates, multiple aspects of the UD system (e.g. technical, social and regulatory aspects) were investigated in the UTS trial to learn about the viability of scaling up UD systems through transdisciplinary inquiry.

The UTS trial was used as a strategic space for not only learning, but also building new professional networks and in the process, facilitating the emergence of UD more broadly within society. Deliberate effort was made to engage with collaborators who were innovative thinkers within their fields, inclined toward creating change toward sustainability. Stakeholders such as councils, water authorities and regulators with vested power and interest in operating within the established system of wastewater management were involved, in what Van De Brugge (2005) defines as an 'innovation network of front runners'. Our collaborators were visionary people willing to be involved in the UTS trial in a process of collaborative learning who were prepared to 'skin their knees' along the way. Interaction with this range of actors both within and beyond the span of the UTS trial brought diversity and novelty into the project, which in turn acted as important stimulants for learning.

The diverse range of actors involved in the UTS trial who contributed to raising awareness of UD in Australia, can be distinguished as the (1) project facilitators, (2) project team, (3) project participants and (4) extended peer networks.

1. *Project Facilitators* managed the trial and had an oversight role in supporting interaction between participants. The core team consisted of three ISF researchers (Cynthia Mitchell, Dena Fam and Kumi Abeysuriya) who took the lead in designing and implementing strategies for transdisciplinary collaboration between government, industry and academic partners as well as the interaction between the project team and the broader range of project participants. The project facilitators met weekly, maintained lines of communication between other members, provided research assistance, developed engagement processes and milestones for critical reflection and monitored and evaluated the progress of the project.

2. *The Project Team* contributed to individual research strands as well as discussing and providing input into the direction of the trial. The project team consisted of academics from three universities (UTS, UWS, UNSW), industry partners (Caroma, National Garden and Industry Association) and government partners (Sydney Water and City of Sydney). Each member of the project team was involved in one or more of the five research strands that met every 1-3 months, depending on the commitment and needs of individuals and the group. In addition, project team members were all involved in large team meetings, where all participants (15 members) met at the end of each action research cycle, approximately every 3-6 months, to critically reflect on the progress of the project, share findings and collaboratively decide on future directions.

3. *The Project Participants* were those involved in using and/or managing the system. These actors included the UTS community of participants (staff and students using the toilets, cleaners and personnel maintaining the UD system). Our plumber, building manager, and the cleaning contract manager participated in and contributed to team meetings.

4. *Extended Peer Networks* expanded the boundaries of the experiment to involve actors external to the immediate network of team members, and included those drawn into the UTS trial along the way, such as members of the property development sector (Nick Storey, Lend Lease) and the plumbing regulation sector (Les Barnard, NSW Department of Fair Trading) as well as the Melbourne water utility, Yarra Valley Water.

The extended peer networks fostered the diffusion of learning from the UTS trial into a diverse range of practice-based networks. This created a positive feedback loop that had the effect of generating new knowledge and facilitating changing perceptions toward UD. Targeted efforts to explain the UTS UD trial in appropriate sectoral forums led to the development of extended peer networks. The invitation to present at the National Plumbing Supply Forum (PSF) in 2010 was particularly valuable. In the PSF we introduced the global phosphorus issue and future wastewater scenarios and illustrated the opportunities for the plumbing sector to contribute to sustainable wastewater management. We also shared our research on UD and provided an overview of current UD installations both locally and internationally. Our aim was to facilitate the plumbing industry's involvement in developing UD innovation. (See Figure 46).

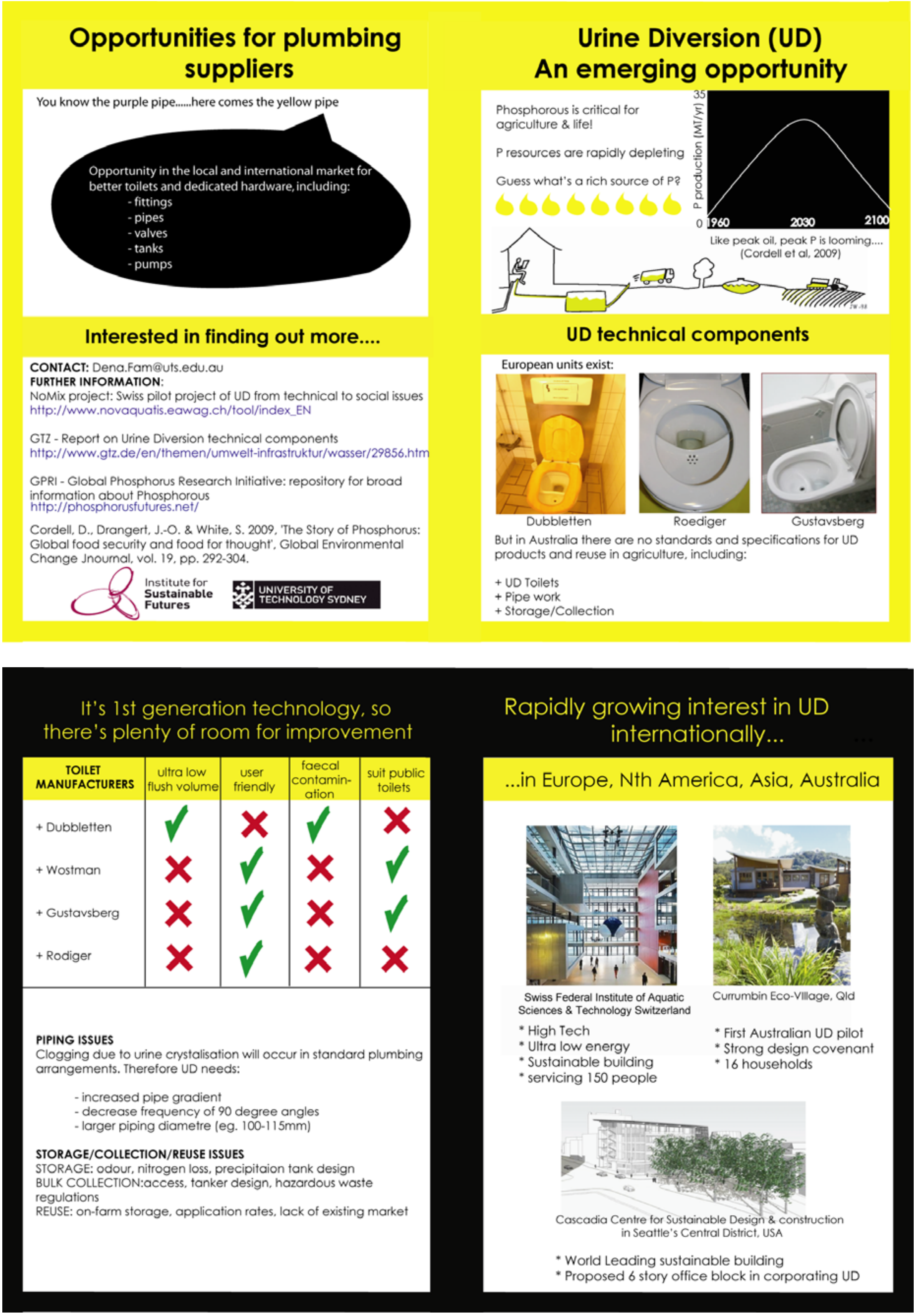


Figure 46: Pamphlet created and shared with industry actors at the National Plumbing Supply Forum, 2010

As a consequence of our involvement in the PSF conference, a number of influential actors were convinced of the potential value of urine diversion, and joined the UTS trial. These actors included the national regulator of plumbing fixtures who contributed regulatory advice in retrofitting UD into existing buildings and a senior hydraulics engineer from one of Australia's leading property development companies (Lend Lease). They recognised that even though the viability of urine diversion is not yet clear, it could become viable in the future, and that there was an opportunity to be involved in the development of UD systems by incorporating urine pipework into buildings that are currently under construction.

With the help of our new development sector partners, the scale of this project's impact significantly increased. Combining our experience, together we were able to prepare a strong and credible argument for the sustainability and financial value associated with future-proofing commercial buildings by including UD pipework at the design stage. We estimated that the additional cost of installing urine pipework at the construction stage of a commercial high-rise building is very small when compared to the cost of the whole building – perhaps as little as 0.2%. In contrast, the cost of retrofitting UD pipework into existing buildings is prohibitive. Our engagement and outreach work through the extended peer network resulted in the very significant outcome of commitments from two quite different players to include urine diversion pipework from urinals in commercial projects currently under construction in Sydney. UTS committed to urine diversion pipework for the 'Broadway Building', the new home for the Faculty of Engineering and Information Technology. Lend Lease designers committed to including UD pipework in their designs for Stage 1 of Barangaroo, Sydney's premier 'green' waterfront development.

To support these commitments to UD pipework, our project team worked closely with our extended peer network to convene key stakeholder meetings to share technical expertise and perceived problems in installing UD systems in multi-storey urban developments. The working group of stakeholders included those from Lend Lease (Property developer), Sydney Water (Sydney water utility), Caroma, Arup (construction company) and the UTS Facilities Management and Operations. Detailed technical findings and developments in both international and local research were shared with industry partners. The lack of clear guidelines for UD in new buildings with waterless urinals was addressed from input from multiple perspectives. An outcome of this collaboration was the development of guiding principles for the installation of UD in multi-storey buildings (see *Appendix 1: Practical pointers for installing UDTs and waterless urinals*), to enable the emergence of 'future proofing' installations to occur. As experience in UD increases, we expect these preliminary guidelines to develop further into the sort of detailed technical guidelines needed for adoption of UD at scale.

To communicate the UTS trial to a broader audience and facilitate shifts in perception toward UD systems, an important part of our strategy was to publish our research in industry journals. What emerged from the public relations exercise at the PSF conference was an increasing interest from industry actors in UD. As a result, our concept of the 'yellow plumber' introduced at that forum, took on a life of its own and emerged in industry publications. The premier national industry journal Plumbing Connection published two articles on the UTS trial and the 'rise of the yellow plumber', the first of which inspired the front cover graphic (see Figure 47). This article was then syndicated and subsequently published by the on-line journal *World Plumbing Connection* (See chapter on *Media & Awards* for further details).

Figure 47: Front cover of Spring 2010 edition of Plumbing Connection, showing graphic inspired by 'yellow plumbing' concept introduced by our team to the National Plumbing Supply Forum that year.

To attract relevant actors into the project and facilitate socio-technical change communication and public relations has been an important aspect of the UTS trial. Our intention was to use the UTS trial to interest and inform industry actors of how UD contributes to sustainability. This evoked a curiosity from industry actors which led to reflection and action on how they might take a leadership role, and facilitate the emergence of UD more broadly.

REFERENCES

Abeysuriya, K., D. Fam, et al. (2010). Transitioning to sustainable sanitation through cross disciplinary, practice-based research: an on-campus pilot of urine diversion at UTS. The 10th international conference of Australasian campuses towards sustainability (ACTS Inc): connecting curriculum and campus. RMIT. Melbourne, Australia: 1-8.

Blume, S. (2008). Two years of experiences from a urine diversion project in GTZ Headquarters, Eschborn, Germany. IWA World Congress and Exhibition. Vienna, Austria, International Water Association.

Cordell, D., J.-O. Drangert, et al. (2009). "The Story of Phosphorus: Global food security and food for thought." Global Environmental Change 19(May 2009): pp.292-305.

Cordell, D., J.-O. Drangert, et al. (2009). "The Story of Phosphorus: Global food security and food for thought." Global Environmental Change Journal 19: 292-304.

Drangert, J.-O. (1998). "Fighting the urine blindness to provide more sanitation options." Water SA 24(2).

Hood, B. (2008). Domestic urine separation is effective in capturing plant macronutrients, nitrogen, phosphorus and potassium. On-site and decentralised sewage and recycling conference - Coming clean: sustainable backyards and beyond. Benalla performing arts and convention centre, Victoria, Australia, Australian Water Association.

Kemp, R., D. Loorbach, et al. (2007). "Transition management as a model for managing processes of co-evolution towards sustainable development." International Journal of Sustainable Development and World Ecology 14: 78-91.

Kolb, D. A., A. C. Baker, et al. (2002). Conversation as experiential learning. Conversational learning: an experiential approach to knowledge creation. A. C. Baker, P. J. Jensen and D. A. Kolb. London, Quorum Books.

Loorbach, D. (2010). "Transition management for sustainable development." Governance: an international journal of policy, administration and institutions 23(1): 161-183.

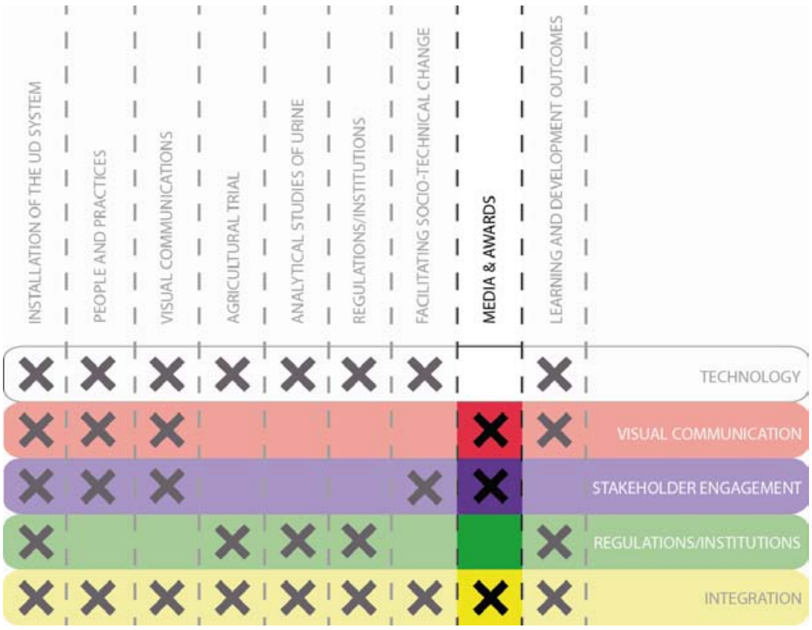
Lopes, A., D. M. Fam, et al. (2012). "Designing sustainable sanitation: involving design in innovative, transdisciplinary research." Design Studies 33(3): 298-317.

MacDonald, S. and R. Narangala (2008). Decentralised or centralised and how to choose? On-site and decentralised sewerage and recycling conference. Benalla, Victoria, Australia, Australian Water Association.

Wilsenach, J. and M. V. Loosdrecht (2001). Separate urine collection and treatment: Options for sustainable wastewater systems and mineral recovery. Utrecht, STOWA.

Wilsenach, J. and M. Van Loosdrecht (2003). "Impact of separate urine collection on wastewater treatment systems." Water Science and Technology 48(1): 103–110.

10 MEDIA, PUBLICATIONS AND AWARDS



Being right on the cutting edge of sustainable innovation requires not only enormous foresight but also a great deal of gumption. Our partners in this urine diversion work have displayed both in spades, and receiving awards is a wonderful way of recognizing their commitment, legitimizing their investment, celebrating our collective achievements, and garnering support for the future.

Prof Cynthia Mitchell, Institute for Sustainable Futures, UTS

The UTS Sustainable Sanitation Project has been prolific in terms of community and industry outreach. Over the two year lifespan of the project we have been invited to discuss the project in 12 different media outlets (both in print and radio), including debating the science of urine diversion with the local community in a national science week event - 'Speed meet a science geek' (see: http://www.scienceweek.net.au/speed-meet-a-geek/).

Our project team has published extensively in the academic arena across different fields of research. A total of ten academic journal publications and conference papers have been published or are in press in the areas of design research, systems thinking and project management.

The project has received local, national and international awards from both the industry and academic communities recognising the work of individual contributions to the project and work of the collective project team to facilitating the emergence and development of urine diversion in Australia (see Figure 48). This section details the awards, publications, and media coverage resulting from the project.

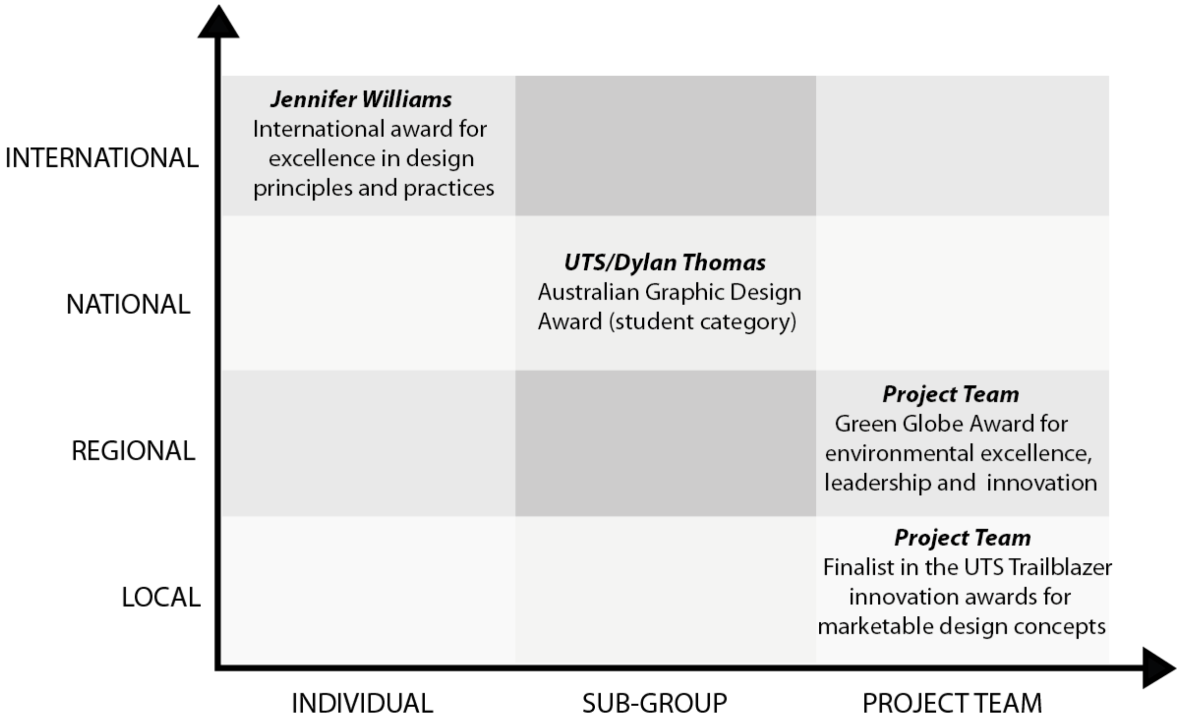


Figure 48: The impressive breadth of recognition awarded to the UTS trial

10.1 AWARDS

2012 The New South Wales Green Globe Awards - Environmental Innovation

The NSW Government's Green Globe Awards are the leading environment awards, recognising environmental excellence, leadership and innovation in NSW. The UTS trial was a recipient of the NSW Green Globe Award in 2012 in recognition of industry collaboration and breakthrough research that contributed to transforming the water industry's perception of sustainable sanitation. A key factor in winning the award, under the category of environmental innovation, was the contribution the UTS trial made to 'market transformation' and engagement of industry partnerships which resulted in UD being included in new property development in Sydney (including the UTS Broadway building and Barangaroo).

(see http://www.environment.nsw.gov.au/greenglobes/2012/innovation.htm#ud)

2012 International Award for Excellence in Design Principles and Practices

Design Principles and Practices is a prestigious international design journal which offers an annual International Award for Excellence for new research or thinking in the area of design principles and practices. The award for excellence for new research or thinking in the area of design principles and practices is targeted at the design knowledge community. All articles submitted for publication in the journal *Design Principles and Practices* are entered into consideration for this award. The awarded publication by Jennifer Williams, a key member of the project team, posited a need to reconsider visual communication design as a more holistic, trans-disciplinary activity and drew on the UTS trial as an exemplary case of how this could be done in practice. By taking the innovative step of involving design academics and students in the earliest stages of planning the UTS trial, our team was able to provide an experimental space to develop evidence of design's significant potential for contribution to system change in transdisciplinary collaboration. The winning publication was: Gwilt I. & Williams J. (2012), Framing futures for visual communication design research, *Design Principles and Practices*

2011 Australian Graphic Design Award 2011 (student category)

The Australian Graphic Design Award recognises excellence and innovation in graphic design. A key goal of the UTS trial was to engage students in collaborating on visual communication for the project. The winning animation, by UTS design student Dylan Thomas, sought to explain the premise behind the phosphorus recovery in the UTS trial by comparing Peak Phosphorus to Peak Oil and visually conveying the importance of considering urine as a potential phosphorus resource for agricultural production (See the winning animation at: http://vimeo.com/13365354).

2010 Finalist in the Trailblazer Innovation Awards (UTS)

The UTS Trailblazer Innovation Awards is an ideas competition that encourages innovation through the development of marketable research concepts. The UTS trial was a very different kind of entrant in this award, which is usually reserved for physical products. Instead our team presented an innovative concept in which the transdisciplinary expertise developed in the project had the potential to be marketed to industry and government stakeholders interested in installing UD. The UTS trial was shortlisted as a finalist in the 2010 Trailblazer Innovation awards.

10.2 INDUSTRY PUBLICATIONS

Jackson, J. (2012), Is there a need for a ‘yellow’ plumber? [on-line] p.50-54 *Plumbing Connection,* http://search.informit.com.au/documentSummary;dn=165748521546699;res=IELENG

Fam, D.M. & Abeysuriya, K.R. (2011), 'Toilet talk', *WME Magazine*, vol. 22, no. 4, pp. 32-32

Kyriakou D., (2010), The yellow plumber [on-line], *Plumbing Connection,* p.56-61, http://search.informit.com.au/documentSummary;dn=717705768071707;res=IELENG

Jackson, J. (2012), Is there a need for a ‘yellow’ plumber? [on-line], *World Plumbing Connection,* http://www.worldplumbinginfo.com/article/yellow-plumber

10.3 MEDIA

Ham M., (2012) Many minds flush with ideas: Collaboration between academics and industry has a flow-on effect on a project's success, *Sydney Morning Herald,* October 6, 2012.

2012, Australian Broadcasting Corporation (ABC) radio interviews with Radio National and four other regional Australian radio stations (Including Newcastle, Darwin, Illawarra and South coast)

Abeysuriya, K.R., Fam, D.M. & Mitchell, C.A. (2012), 'Reinventing the toilet - Urine diversion where it's needed most', The Conversation, vol. 24 October http://theconversation.edu.au/reinventing-the-toilet-urine-diversion-where-its-needed-most-9576

Fam, D.M. (2012), 'Our ancestors recycled their urine: why shouldn't we?', *ABC Science online - In Depth*, Web article, http://www.abc.net.au/science/articles/2012/01/31/3415550.htm

2011, Catalyst, *Peak Phosphorus* http://www.abc.net.au/catalyst/stories/3166841.htm

2011, *The Land*, Hawksbury know-how, http://www.theland.com.au/
This article discusses the honours project by student Tom Venables (UWS) who was involved in recycling urine from the UTS trial to gauge its potential as a plant fertiliser.

10.4 REFEREED PAPERS AT ACADEMIC CONFERENCES/SYMPOSIUMS

Fam D & Lopes A, (2012), 'Supporting system change and niche practices through participatory qualitative social research, Beyond Behavioural Change Symposium, RMIT, Melbourne, 2012

Fam D, Mitchell C, Abeysuriya K & Lopes A, (2011), 'Facilitating social learning in transdisciplinary collaboration: a socio-technical experiment in implementing sustainable sanitation', International Society of Systems Scientists, Hull, UK in July, 2011.

Fam D, Mitchell C & Abeysuriya K, (2011),'Learning to facilitate learning', *2nd International Conference on Sustainability Transitions – Diversity, plurality and change: breaking new grounds in sustainability transition research* at Lund University, Lund, June 2011.

Lopes, A, Fam, D & Williams, J. (2010), 'Designing sustainable sanitation through transdisciplinary research: A pilot project of nutrient recovery and reuse', *Young Creators for Better City and Better Life - Cumulus Conference*, Tongji University, Shanghai China, September 6-10th

Abeysuriya, K.R., Fam, D.M., Hagare, P. & Williams, J. 2010, 'Transitioning to sustainable sanitation through cross disciplinary, practice-based research: an on-campus pilot of urine diversion at UTS', International conference of Australasian campuses towards sustainability, Melbourne, Australia, September 2010 in *The 10th international conference of Australasian campuses towards sustainability (ACTS Inc): connecting curriculum and campus*, ed RMIT, RMIT, Melbourne, Australia, pp. 1-8

Sankaran, S, Abeysuriya K, Gray, J. & Kachenko, A. (2010), 'Closing the loop: A systems thinking led sustainable sanitation project in Australia', 54th Meeting of the International Society for the System Sciences, Waterloo, Canada, July 2010

10.5 JOURNAL PUBLICATIONS

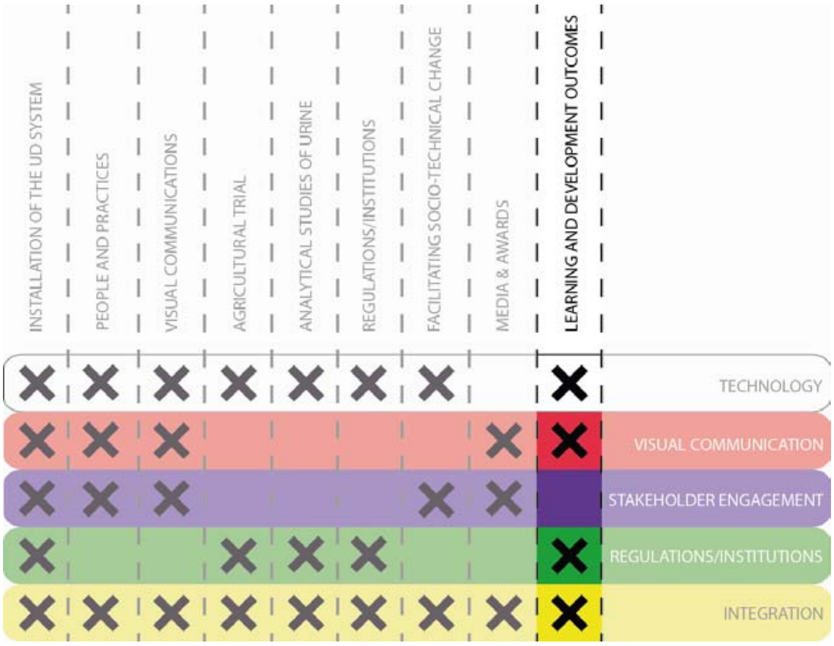
Gwilt I. & Williams J. (2012), Framing futures for visual communication design research, *Design Principles and Practices*

Lopes, A., Fam, D, Williams, J. (2011), 'Designing sustainable sanitation: involving design in innovative, transdisciplinary research', *Design Studies*, Elsevier, UK

Fam D, Abeysuriya K, Mitchell C & Lopes A (in press), Facilitating sustainable innovation by designing socio-technical experiments as social learning systems, *Journal of Cleaner Production*

Sankaran, S, Abeysuriya K, Gray, J. & Kachenko, A. (under review), 'Closing the loop: A systems thinking led sustainable sanitation project in Australia', *Systems Thinking and Behavioural Change*

11 LEARNING AND DEVELOPMENT OUTCOMES



'… as a collaborator [in the UTS trial] I became aware of the whole process of UD, not just the end product… I didn't realise the complex design issues that needed to be considered, the logistics and maintenance of such facilities….it certainly has opened up my eyes to the other side [of actually installing a UD system], and not just the end product [that relates to the horticultural industry]'.

Dr Anthony Kachenko, Environmental & Technical Policy Manager Nursery and Garden Industry Australia

In trialling UD within the university setting we sought not only to answer the research questions of interest, but also to provide high quality spaces for experiencing challenges, leading to significant learning and development outcomes. We wanted to make these opportunities available for three distinct groups of participants: students at various stages of their training (undergraduate and postgraduate); early career researchers within the project team; and our industry partners.

11.1 OUTCOMES FOR STUDENTS

The university setting provided opportunities for mutual benefits to academic partners, students, and the project. In addition to having goals for academic publications that the project helped meet (with collaborations providing very positive learning experience, as illustrated by the chapter quote), our academic partners had learning and teaching responsibilities and commitments that could be fulfilled through offerings for practice-based learning related to the UTS Sustainable Sanitation Project. Participating students were able to gain valuable research experience through engagement in a live research project. Student research outcomes made a valuable contribution to the project. Students also helped enormously with diffusing knowledge about peak phosphorus in general and outcomes of this project in particular, through official and social media outlets as well as through peer networks.

The project was able to provide excellent opportunities across the full range of tertiary student degrees: undergraduate course work, undergraduate research theses, Masters coursework projects, and Doctoral research studies. The key activities and outcomes are summarised below.

a. Visual Communication research strand & undergraduate Design programs

Our visual communications academics Ms Jennifer Williams (UTS) and Dr Abby Lopes (UWS) used the project in their undergraduate subjects '*Information Design*' for 3rd year design students at UTS and '*The Professional Brief*' for 2nd year design students at UWS, as the context for practice-based learning, allowing students to put into practice what had been learnt in the curriculum. Students created outputs in two broadly defined areas: creating identity for the project, and designing understanding/engagement. The 'identity' outputs included a range of logos and branding solutions to provide visual recognition triggers within the campus. The 'understanding/engagement' outputs included a range of multimedia artifacts such as information posters (with the 'best' poster installed on the back of the pilot toilet cubicle doors), designer toilet paper, and an animation that won a Gold/Distinction Australian Graphic Design Award (2010).[63]

b. Technology research strand & undergraduate Engineering 'Capstone' projects

Engineering students at UTS are required to undertake a Capstone Project in their final year where they take individual responsibility in completing a significant engineering project. Our Faculty of Engineering & IT academic Dr Prasanthi Hagare designed Capstone Project briefs to support the UTS Sustainable Sanitation Project. A single student-project match was made with Mr Tristan Whitley who undertook a review of potential site options for the demonstration installation of urine diverting toilets, and installation issues following a literature review.

c. Technology research strand & undergraduate Agriculture Honours project

Undergraduate students in Agriculture who meet high standards of academic performance criteria can take an additional year of study and undertake an Honours research project aligning with their academic supervisors research interests. Our collaborators Prof Bill Bellotti (School of Natural Sciences, UWS) and Dr Anthony Kachenko (Nursery & Garden Industry Australia) co-supervised Mr Tom Venables in conducting pot trials to evaluate the bio-availability of phosphorus and other essential plant nutrients present in urine, and salinity impacts on the soil used. See chapter on *Agricultural Trial* for further details.

d. Regulations and Institutions strand & Masters in Environmental Law

Ms Victoria Burston, Sydney Water staff member who represented the Sydney Water Corporation (SWC) collaboration partner for the latter part of the project, was completing her Masters in Environmental Law at Macquarie University. She chose to use our project to scope the topic for her coursework research paper on 'the regulation surrounding the bulk transport of urine destined for reuse on agriculture'. In an unusual feat of cross-university collaboration between Macquarie, UTS, and UNSW, our project partner Associate Professor Janice Gray (UNSW Law faculty) provided supplementary supervision.

---

[63] For news release and link to animation see:
http://datasearch.uts.edu.au/dab/news-events/newsarchive-detail.cfm?ItemId=23868

11.2 OUTCOMES FOR EARLY CAREER RESEARCHERS

The project team included four early career researchers: Ms Dena Fam (doctoral research candidate at ISF); Ms Jennifer Williams (lecturer in Visual Communications at UTS and doctoral candidate at Monash University), Dr Dana Cordell (postdoctoral fellow at UTS), and Dr Kumi Abeysuriya (research consultant at ISF). The project provided the context for numerous publications and presentations, and media engagement (see chapter on *Media & Awards*) that helped build the careers and reputations of the ECRs.

- The project was one of the primary case studies included in Dena Fam's doctoral research. Fam's formal role was Project Manager of the UTS trial. This was in line with the postgraduate research training at ISF that supports students in working across multiple disciplines with the aim of creating tangible outcomes toward sustainable futures. Fam's research and theoretical understanding of transition management (Kemp, Loorbach et al. 2007) from her doctoral investigation were practically applied in designing the project. Fam further met her doctoral research needs by including supplementary activities outside the core scope of the project, such as evaluating the community of practice and social learning that developed within the project. In addition to supporting her doctoral research, the project also enabled her to network and establish herself as a national and global expert in UD through her participation in Sustainable Sanitation forums, ABC 'Meet the Geek' program, and other media opportunities.

- Jennifer Williams was a very active participant in the Visual Communications research strand, which also enabled her to significantly advance her publications record. The project gave her the opportunity to develop significantly as a researcher and to disseminate her work, starting with her first ever conference presentation based on the project in 2010, to contributing to several further publications for conferences and peer reviewed journals, culminating with winning a prestigious award in the design field "International Award for Excellence in the area of design principles and practices" for her co-authored paper (Gwilt & Williams 2011) submitted to the journal 'Design Principles and Practices' that was placed amongst the ten highest-ranked papers emerging from the referee process with a special invitation to present at an international conference in Prague. In her role as a lecturer in Design, she was able to inspire her students with the practice-based research offered by the project that yielded very high quality student outputs (see chapter on *Visual Communications*)

- Dana Cordell's involvement in the Integration research strand provided opportunities for her to strengthen the linkages between the project, her earlier research on urine diversion in Australia (Cordell 2006), and her ongoing research on peak phosphorus. The outcomes of the project provided a practical case study of how a sustainable phosphorus measure (in response to peak phosphorus) could be implemented in the Australian context and the specific challenges and opportunities it would face in an institutional setting. Further, this very local scale project complemented the more global and national scale research she is undertaking. Regarding learning in relation to transdisciplinary research, this project gave her insights into how the application or operationalisation of important transdisciplinary principles (such as engagement of stakeholders in the research process, and enabling an evolving methodology) can function in practice, and highlighted some unforseen pitfalls and opportunities to improve practice (such as managing multiple and potentially conflicting needs/agendas, or effectively keeping such a large group up-to-speed on a rapidly changing project).

- The project enabled Kumi Abeysuriya to expand her research skills through her close involvement in the Technology and Integration research strands, which gave her many opportunities to exercise creativity and extend her research practice. It also gave her valuable opportunities to develop her professional networks through participation in meetings with the project's collaborators and extended peer networks, and through engagement in conversations/correspondence with researchers and practitioners both locally and internationally. Her aspirations to contribute towards sustainable sanitation in developing countries, the topic of her PhD thesis, were supported by her involvement in the project, in particular the trial and demonstration of sustainable sanitation options in developed countries which she posits is a pre-requisite for dissemination to developing countries. She was also able to advance her publications record and conference presentation experience.

11.3 OUTCOMES FOR INDUSTRY PARTNERS

The project helped our industry collaborators to understand what it means to do research in quite different ways. Action research and the ability to change scope and direction midway through the project in particular, was very different to the less flexible projects customarily undertaken by our partners. The learning and development in this respect was highlighted by one partner's reflections: "*I think at the beginning I was very unclear of the scope of the project and then I realised the reason I'm unclear about the scope is because it is actually changing".*

The project also enabled productive relationships between partners for further research and networking. For example, representatives from Caroma (GWA) and Lend Lease are progressing plans to conduct research on installations of waterless urinals in multi-storey buildings, to contribute to developing guidelines for urine diversion in this important market sector for both organisations. Sydney Water organised and hosted a field-trip to their wastewater treatment plant where treated wastewater is reused for irrigation in adjoining pasture land, which provided a wonderful opportunity for project partners to discuss practical issues around urine reuse as well as build further relationships.

REFERENCES

Abeysuriya K., Fam D., Hagare P. & Williams J. (2012). 'Transitioning to sustainable sanitation through cross disciplinary, practice-based research: an on-campus pilot of urine diversion at UTS'. Proceedings of The 10th International Conference of Australasian Campuses Towards Sustainability (ACTS Inc).: Connecting Curriculum and Campus, Melbourne September 2010.

Cordell, D.J. 2006, 'Urine diversion & reuse in Australia: A homeless paradigm or sustainable solution for the future? (Masters thesis)', The Tema Institute, Department of Water and Environmental Studies, Linkoping University, Sweden, pp. 1-141.

Gwilt, I., and Williams, J., 2011. 'Framing Futures for Visual Communication Design Research'. Design Principles and Practices: An International Journal, Volume 5, Issue 5, pp.81-98

UTS:INSTITUTE FOR SUSTAINABLE FUTURES

TRANSITIONING TO SUSTAINABLE SANITATION – A TRANSDISCIPLINARY PILOT PROJECT OF URINE DIVERSION

Appendix 1

Practical Pointers for Installing UDTS and Waterless Urinals

APPENDIX 1: PRACTICAL POINTERS FOR INSTALLING UDTS AND WATERLESS URINALS

WHO SHOULD READ THIS? Plumbers, building designers, hydraulic engineers, researchers, and urine diversion enthusiasts.

This appendix draws together some recommendations that are not available elsewhere, and that we learned through hard-won experience. As far as we can tell, no-one else has published this kind of thing. It contains all kinds of insights about installing UD systems that would have been great to know up-front in the UTS trial. It is intended to provide a useful starting point for practitioners who might be planning to install UDTs or waterless urinals in Australia.

In Section A1.1 we provide guidance principles for installing urine pipework in multi-storey buildings that was developed with our industry collaborators, as referred to in several previous chapters (3,8,9,11).

Section A1.2 summarises our practical tips about:

- Making allowance for later replacement of a UDT with a conventional toilet
- Planning for users' learning how to use a UDT correctly
- Things to consider for collecting urine samples for analysis.

In addition, Appendices 2 and 3 consist of our documents to fulfilling regulatory and institutional requirements, that may be useful for others as examples,:

- Appendix 2 contains our application to the plumbing regulator NSW Department of Fair Trading for *Performance-based Installation* of our UDTs, as an example of documentation for complying with plumbing regulations outside the Plumbing Code (installing products with no Australian Watermark certification).
- Appendix 3 provides our *risk management strategies* for others to consider and extend/adapt for risk management, particularly for UD projects in institutional contexts.

The recommendations and practical pointers here are not intended to be comprehensive but focussed on specific learning outcomes from our project. Please also consult other practical guidance resources such as those listed in the References section at the end of this Appendix.

A1.1 RECOMMENDATIONS FOR URINE PIPEWORK IN MULTI-STOREY BUILDINGS

The formation of struvite deposits in pipework must be managed so urine flow is not obstructed. In the case of multi-storey buildings where the option of installing pipes at steep gradients are limited, the maintenance of less steep pipework is critical.

The National Plumbing Regulators Forum has conducted research and published advice on the installation and maintenance of urinal pipework to manage struvite (NPRF 2009). It recommends regular flushing by utilizing upstream water using fixtures. When collecting urine for reuse, flushing water needs to be diverted to sewer rather than the collection tank where it would dilute the urine and take up additional volume in the tank.

Our extended peer network of collaborators from the building industry, with our facilitation, deliberated on design issues for urine pipework in upcoming buildings (see chapter on *Facilitating socio-technical change* for contextual details). As a result of discussions, four guiding principles for the design of UD systems in high rise buildings were identified:

- An arrangement for flushing the pipes is needed to limit struvite buildup in horizontal lines. Use of rainwater to dose/flush lines daily or weekly, and/or setting the furthest urinal in a bank to flush automatically to periodically to clean lines, are two possible options.
- To prevent dilution of urine being collected, a diversion valve is needed so that water used in flushing the lines could be directed to the sewer.
- The final design should allow for periodic jet cleaning to be provided.
- The gradient for the urine pipework should be increased as much as possible[64] from the 1:65 that is currently viewed as the most efficient self-cleaning grade for urine pipe work.

A design concept for installing waterless/controlled low-flush urinals[65] in high-rise buildings, in alignment with the principles was developed by our collaborator from the property developer, Lend Lease (Figure 49). This led to some additional points being highlighted:

- The urinal fixture discharge pipe (horizontal) should be sized to accommodate a jetter (at least 50 mm) for jet cleaning.
- Each urinal fixture discharge branch (horizontal) should have a clear-out at the end of the line.
- The urine collection system needs suitably designed protection against the event of a surcharge or blockage in the sanitary (sewer) system.
- Tanks and pipework should be configured to minimize nitrogen losses (also see chapter on *Installation of the UD system*, and Von Muench et al. 2009).

[64] A grade of 1:40 was discussed as potentially viable, while steeper slopes where possible are preferable.
[65] The concept included programming the urinals to flush only at set times coordinated with the diversion of flushing water to sewer rather than the urine tank.

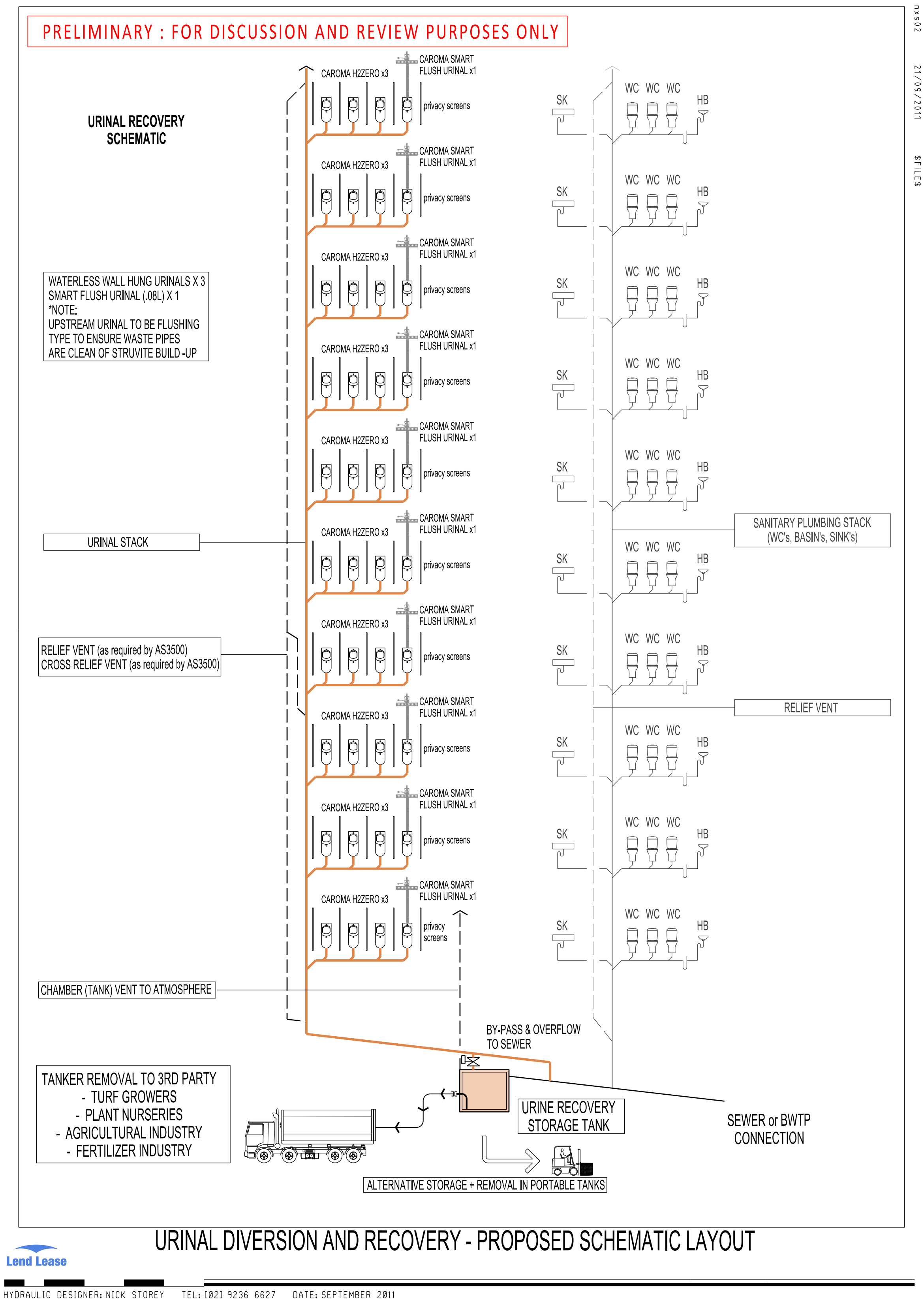


Figure 49: Concept for hydraulic services for urine collection (reproduced with permission from Nick Storey, Lend Lease)

A1.2 PRACTICAL TIPS FOR INSTALLING UDTS WITH ALLOWANCE FOR LATER REPLACEMENT

When installing a UDT, you would probably want to provide the option for owners to replace it with a different UDT or a conventional toilet at a later date. Take into account the differences in their relative dimensions from the beginning so replacement does not become a major renovation.

With both models of UDTs installed at UTS, the back of the toilet (that is usually expected to be against the wall) was closer to the large wastewater outlet than a typical Australian toilet (See Figure 50). When designing for installing a UDT, make sure the toilet is designed so the wall at the back of the toilet does not need to be moved when replacing the toilet.

Figure 50: The back of the UDT stands closer to the wastewater outlet than a standard Australian toilet. A image shows the wooden block that was placed in the gap to give stability that the wall would normally have provided to the UDT's cistern.

A UDT's footprint (see Figure 51) is generally longer than a standard Australian toilet's, since they need to accommodate two bowls. When replacing with a standard toilet, the hole made in the floor for the urine pipe may become exposed. Save some spare floor tiles at time of installation for repairing the floor later, or choose a replacement toilet with a footprint that is long enough to conceal the repair.

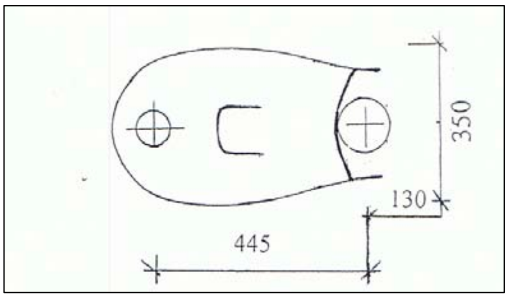


Figure 51: Dubbletten manufacturer's drawing of UDT footprint

A1.3 RECOMMENDATIONS FOR PLANNING SUPPORT FOR UDT USERS' LEARNING

New users who have been accustomed to conventional toilets will take a little time to adjust their practices to use a UDT correctly, and it is important to plan for this. There are two areas in particular, that are inconsequential with conventional toilets but matter greatly for UDT operation: the placement of used toilet paper, and the sitting angle/position on the toilet.

For our users, routinely dropping their toilet paper so it lands in the rear bowl rather than the front urine bowl took some learning (and we still have occasional problems). Ingrained practice norms meant that people 'unconsciously' tended to drop the paper in the front. It is essential to have permanent signage in the toilet to remind people to ensure they drop their paper in the back, and to inform visitors. Include advice that if they accidentally drop their paper in the front, they need to pick it up and put it in the back to avoid blocking the urine pipe.

Users also need to be mindful of sitting in an appropriate position to ensure good separation of urine and faeces. In the early days, we had several incidents of faecal matter ending up in the urine bowl, to the dismay of our cleaning staff (especially with the Wostman UDT model). Our cleaning staff observed that women often seemed to 'perch' at the front end on public toilets the toilet rather than sit back on the seat. Include signage to alert people of the need to sit back.

Providing signage, as well as tools to accommodate accidents, will support users. Figure 52 shows an example of signage we developed for households participating in the Victorian study (Mitchell et al 2010, also see chapter on *Why?*) – also reminding those doing maintenance about suitable cleaning products to prevent contaminating the urine[66]. We also provide plastic tongs[67] for people to transfer their misplaced paper with, as some users prefer not to use their hands. A toilet brush is left in the cubicle to clear accidental faecal marking[68] (during the trialling of the Wostman model toilet (see chapter on *Installation of the UD system*) we also provided a small test-tube brush to clear blocking of the exposed urine outlet – mainly for use by the cleaning staff).

Enabling peer learning can create a sense of camaraderie and fun as well as a providing channel to identify problems and gain support. Significant learning occurred through our graffiti board where users shared their experiences and perceptions (see chapter on *People and practices*). A web based discussion forum can be an alternative in a different

[66] See Kvarnström et al. (2006) for more on maintenance routines.
[67] Plastic will minimise damage to the porcelain surface. Unexplained scratches appeared in our UDT urine bowl before we provided plastic tongs, which we suspect were caused by an attempt to transfer misplaced paper with a metal tool.
[68] Toilet brushes are usually not left in public toilets in Australia. We also note that the appearance of faecal markings on the UDT is no worse or no more frequent than observed in standard toilets.

context. Where users have less access to the internet, they can be interviewed for feedback and comments which can be shared through community events or newsletters[69].

Figure 52: Example of signage for UD toilet users

A1.4 CONSIDERATIONS FOR COLLECTING 'FRESH' URINE SAMPLES

In the published literature, urine samples are most frequently collected from the urine tank – which makes sense in most cases when the tank urine will be reused. If you also want to collect samples of 'fresh' urine for research purposes, this section will help you to design a better system than we did, from our learning from failure.

The sampling system needs to be designed to *hygienically* collect samples of fresh urine that is *representative* of the user population. This would firstly mean minimizing opportunities for contamination of urine from the pipework - avoiding sites where urine can stagnate and breed microorganisms such as bends or corrugations in pipes. If it is not possible to eliminate the odour trap (e.g., with the Wostman model toilet, or potential regulations elsewhere) we would bypass the trap and divert urine to the sampling apparatus before it passed the trap. Another modification would be to reduce the entry of

[69] This was the channel chosen with the Victorian trial (Mitchell et al. 2011). The main limitation of interviews is that experiences and thoughts are not captured immediately as they occurred. Diaries can be used although we had limited success with these (ibid, Appendices).

particulate sediments into the urine samples. A design concept for decanting urine before it enters the sampler is shown in Figure 53)

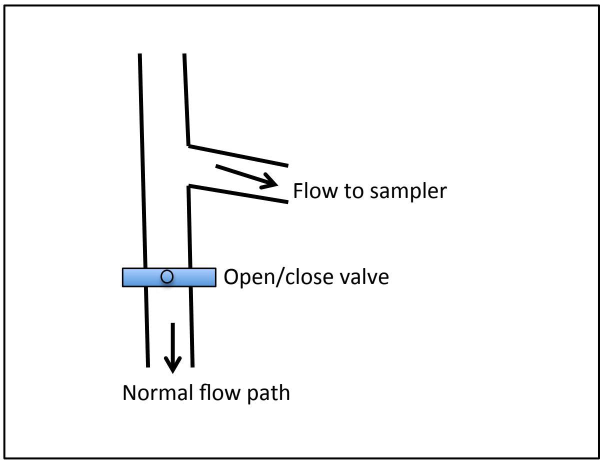


Figure 53: Concept to decant particulate matter before filling sampling apparatus

Urine content is dependent on individual characteristics (diet, medication, exercise, lifestyle, genetics etc), so samples that are *representative* of the user population would need to have a large enough number of contributors to the urine sample than we did, while at the same time maintaining the 'fresh' characteristics of urine (perhaps through some refrigeration). We didn't fully consider the former and instead traded it off against the latter, so our samples were personalised by the very small number of contributors (8-15 individuals) leading to variable samples (see chapter on *Analytical studies of urine*). Others may be able to develop a more clever design that meets both requirements by considering them upfront.

If we were to repeat the sampling, we would retain the basic design concept for a simple device to intercept urine from the UDT or urinal with overflow to the sewer when its capacity was reached. Two other features to consider in addition to the above would be (1) to enable mixing the urine within the sampler before filling sample vessels so that more uniform sub-samples are created (2) to flush the urine pipework and sampling apparatus before each sampling event, to improve the hygienic quality and minimise contamination from organic and inorganic matter in the pipework.

Concluding remarks

We are still in the early stages of learning about the potential of urine diversion, so sharing lessons learned and practical tips in installing these systems is good for everyone involved because it allows us all to learn through our failures rather than to repeat the same mistakes others have made. In this way, the whole field of UD research and practice grows faster and more effectively. It is in this spirit that we offer these practical tips.

ACKNOWLEDGEMENTS

We would like to thank the following individuals/organisations for their valuable contributions to the research in this chapter.

- *Nick Storey* (Lend Lease), for his enthusiasm and initiative in seeking to develop design guidelines for urine diversion pipework in multistorey buildings, for the UTS FEIT building and Lend Lease developments.
- Our extended peer network from the development sector for their contributions in developing guidance principles; Gregory Graham (UTS Program Management Office); Greg Karmish (Arup); Ingrid Saywell (UTS Program Management Office);
- *Les Barnard* of Sydney Water, representing the plumbing regulator, for contributions to our extended peer network on designs for urine pipework in multi-storey buildings, with support from *Luke Di Michiel* of GWA Group Ltd. (Caroma Dorf).

REFERENCES

Mitchell, C.A., Fam, D.M. & Abeysuriya, K.R. 2011, 'Mutual Learning for Social Change: Using social research to support the introduction of urine diverting toilets in the Kinglake West Sewerage Project', Institute of Sustainable Futures, Sydney, pp. 1-23. http://www.isf.uts.edu.au/publications/mitchelletal2011mutuallearningkinglakefinalreport.pdf

NPRF 2009. NPRF Advisory Note: Waterless Urinals. http://www.pic.vic.gov.au/resources/documents/NPRF_Advisory_Note_-_Waterless_urinal.pdf

E. Kvarnström, K. Emilsson, A. Richert Stintzing, M. Johansson, H. Jönsson, E. af Petersens, C. Schönning, J. Christensen, D. Hellström, L. Qvarnström, P. Ridderstolpe and J.-O. Drangert 2006. Urine Diversion - One Step Towards Sustainable Sanitation. EcoSanRes Programme, Stockholm Environment Institute, Stockholm, Sweden. http://www.susana.org/lang-en/library/library?view=ccbktypeitem&type=2&id=192

Von Muench, E., and Winker, M., 2009. Technology review on urine diversion components - Overview of urine diversion components such as waterless urinals, urine diversion toilets, urine storage and reuse systems. Deutsche Gesellschaft für Technische Zusammenarbeit GmbH (GTZ) http://www.susana.org/lang-en/library?view=ccbktypeitem&type=2&id=875

UTS:INSTITUTE FOR SUSTAINABLE FUTURES

TRANSITIONING TO SUSTAINABLE SANITATION – A TRANSDISCIPLINARY PILOT PROJECT OF URINE DIVERSION

Appendix 2

Application for Performance Based Installation

ALTERNATIVE SOLUTION

"Urine diversion toilets and sampling system"

Prepared by

Dena Fam, Kumi Abeysuriya & Cynthia Mitchell

Institute for Sustainable Futures

Table of Contents

Appendices

1 Introduction

1.1 Background

The Institute of Sustainable Futures has been awarded a cross disciplinary research grant to trial nutrient recovery from sewage in the institutional setting of the university campus.

An initial pilot project of 2 urine diversion toilets (UDT) for research purposes has been installed at 235 Jones St, Ultimo, in Building 10, on Level 11 with one toilet installed in both the male and female toilet blocks.

The UDT installed in the female toilet block is connected to a urine collection and sampling system on the floor below (Level 10), situated within the service ducting cupboard (refer Appendix 1).

1.2 Proposal

An ‘alternative solution’ is sought under Part A2.2 of the *Plumbing Code of Australia 2004* for the installation of a urine diversion toilet connected to a urine sampling system (refer to Appendix 1)

2 SCOPE, LIMITATIONS AND ASSUMPTIONS

2.1 Scope and limitations

- This report is limited to the nutrient recovery, collection and sampling system installed in Building 10, Level 10 & 11, 235 Jones St, Ultimo, NSW.
- The 'alternative solution' as detailed in Section 4 of this report refers to both the installation of the urine diversion toilets in both the men's and women's toilet block and the urine collection and sampling system connected to the women's toilets only.
- This installation has been piloted for research purposes only

2.2 Assumptions

- The 'alternative solution' has been installed by a licensed plumber
- The 'alternative solution' is generally configured to the details supplied (Refer to Appendix 1

3 CODES AND COMPLIANCE

3.1 Referenced Documents

The documents referenced are related to the design criteria below:

- AS/NZS 3500.2 (Australian and New Zealand Plumbing Code)

4 Clause A2.2 Evidence of Suitability

Evidence to support the use of a material, product, design, form of construction or installation meets:

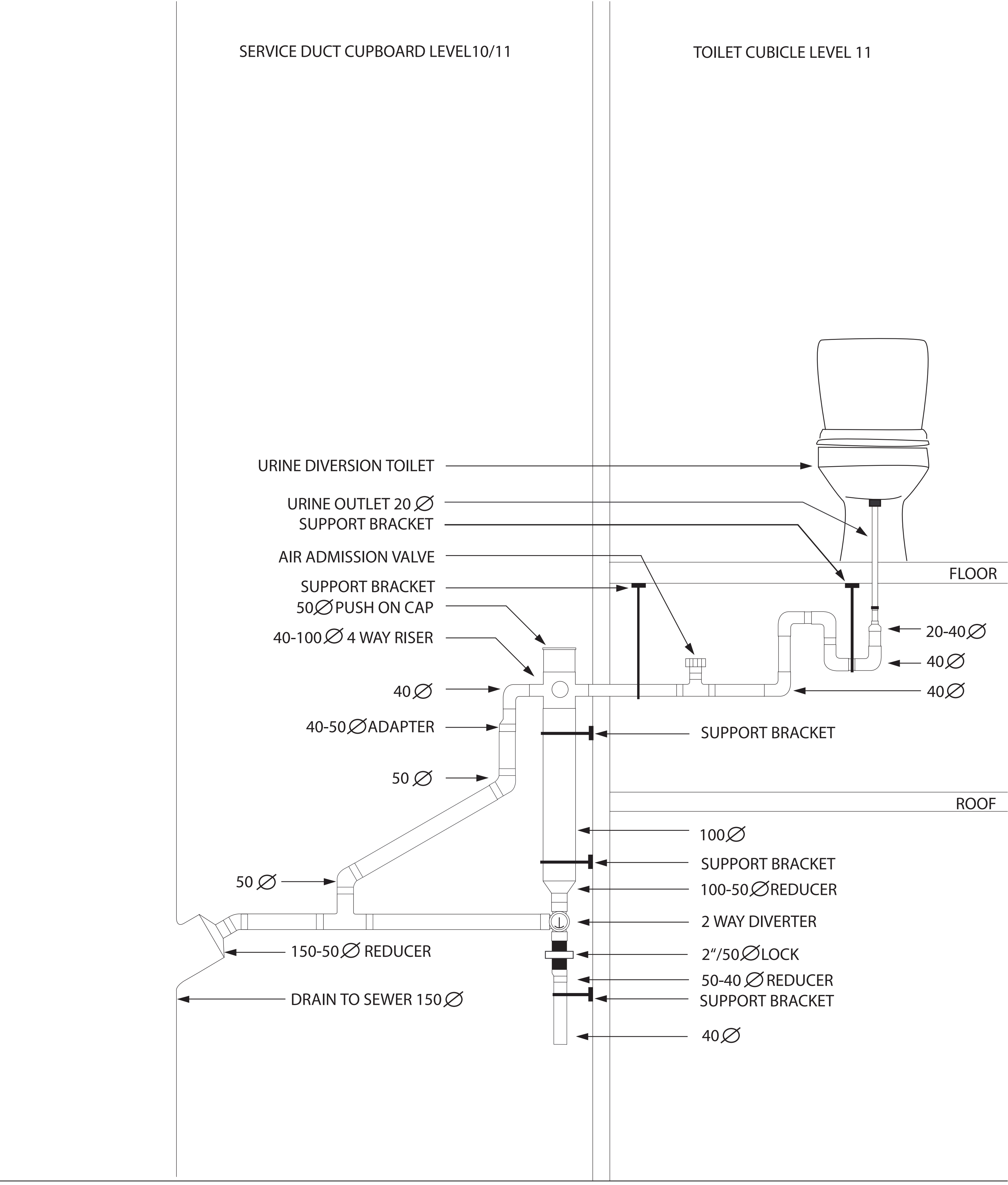
(a) *Performance Requirement* or
(b) *Deemed-to-Satisfy Provision* may be in the form of one or a combination of the following:

4.1 Design/Construction/Installation – Alternative Solution		
Item No.	***Design-Construction-Installation***	***Comments***
1	Certification mark - (WaterMark)	All pipes, fittings and some fixtures used in this alternative solution are Watermark approved..
2	Compliance with the requirements of *Part G* of the *Plumbing Code of Australia.*	The following fixtures are not WaterMarked certified; • Wostman toilet suite • Dubbletten toilet suite
3	A report issued by the Research Project Manager showing that the material, the design, construction and installation has been submitted to the Evidence of Suitability listed in the report, and setting out the results of those tests and any other relevant information that demonstrates its suitability for use in the *plumbing* installation	Refer to this document and accompanying appendices.
4	A statement from a *professional engineer* or other appropriately qualified person which: Certifies the project is for research purposes, the material, design, form of construction and installation does not comply with the requirements of the *Code,* related Standard and WaterMarked products.	Refer attached statement from Les Barnard
5	A statement from a *professional engineer* or other appropriately qualified person which: Sets out the basis on which this project is given and the extent to which relevant *specifications* or other publications have been relied upon	Refer attached statement from Cynthia Mitchell (Chief Investigator)
6	Any other form of documentary evidence that correctly describes the properties and performance of the material, form of construction or installation and *adequately* demonstrates its suitability for use in the *plumbing* installation	Refer attached data and evidence supplied in this submission.

The Alternative Solution detailed in this document refers specifically to the installation of a urine separating toilets. The table below outlines the evidence of suitability used in this project.

4.2 Code Authority & Compliance – Alternative Solution			
Item No	***Suitability***	***Code/Authority Compliance***	***Comments***
1	Is the *Alternative Solution* proposed in conflict with the general intent of AS/NZS 3500	AS/NZS 3500	The installation conflicts with the intent of AS/NZS 3500.2
2	Is the *Alternative Solution* proposed a threat to health and hygiene issues?	NSW Health	Refer attached statement from Dr Kay Power (Project representative from NSW Health)
3	Is the *Alternative Solution* proposed detrimental the design intent of the existing plumbing system being connected to?	Sydney Water	Refer attached statement from Les Barnard
4	Is there evidence the *Alternative Solution* proposed has been used in other regulated jurisdictions	Institute of Sustainable Futures	Refer attached statement from Cynthia Mitchell (Chief Investigator)
5	Does the *Alternative Solution* proposed directly conflict with any clauses in the PCA or Standards	Yes	AS/NZS 3500.2

APPENDIX 1 - DETAIL OF URINE DIVERSION AND SAMPLING SYSTEM



ALTERNATIVE SOLUTIONS SUBMISSION: URINE DIVERSION TOILETS AND SAMPLING SYSTEM

APPENDIX 2 – QUALIFIED STATEMENT – LES BARNARD (SYDNEY WATER)

Re: Alternate Solution submission – "The project is for research purposes, the material, design, form of construction and installation does not fully comply to the deem-to-satisfy requirements of the *Code,* related Standard and WaterMarked products."

I have reviewed the research project plan and scope of procedures, the proposed method of urine separation by means of innovative products from oversea, Wostman and Dubbletten toilet suites will not meet the requirements of Standards for certified products. The design of the sanitary plumbing to convey the waste from these fixtures to a point of storage will not meet the requirements of the Standard AS/NZS 3500.2.

The sanitary installation from the fixtures to the storage vessel will by innovative and may require alteration from time to time to maintain health and safety standards within the building.

The proposed of the sanitary design has the intent to follow AS/NZS 3500.2 principles where possible. The alternative solution would not be detrimental to the existing hydraulic system.

NSW Health will monitor the project installation for health and safety requirements.

Alternative solution; Performance requirements.

Sanitary plumbing systems

The sanitary plumbing system conveying water-borne waste must be designed constructed and installed in such a manner as to:

(a) Convey sewage excluding urine from the trial fixtures to the existing sanitary system.

(b) Avoid the likelihood of loss of amenity due to blockage and leakage;

(c) avoid the likelihood of the ingress of inappropriate water, sewage, foul air and gases from the system into the building.

(d) Provide adequate access for maintenance of mechanical components, operational controls and for clearing blockages.

(e) Provide venting to the sanitary system and/or storage vessel if required or requested by others.

I do not believe the installation of this alternative solution would be detrimental to the existing hydraulic system.

Yours faithfully

Les Barnard

APPENDIX 3 QUALIFIED STATEMENT – DR KAY POWER (NSW DEPT HEALTH)

APPENDIX 4 CURRICULAR VITAE – PROFESSOR CYNTHIA MITCHELL (UTS/ISF)

APPENDIX 5 - QUALIFIED STATEMENT – PROFESSOR CYNTHIA MITCHELL (UTS/ISF)

UNIVERSITY OF TECHNOLOGY SYDNEY

31st January, 2011

Cynthia Mitchell
Professor
Institute of Sustainable Futures
Main Campus
PO Box 123 Broadway
NSW 2007 Australia
T: +61 2 9514 0000
F: +61 2 9514 0000
Your.Name @uts.edu.au
www.uts.edu.au

UTS CRICOS PROVIDER CODE 00099F

STATEMENT FROM A QUALIFIED ENGINEER OR SIMILAR

PROFESSOR CYNTHIA MITCHELL PhD, BEng (Hons I), Hon DTech
(PROJECT PRINCIPAL AND CHIEF INVESTIGATOR, UNIVERSITY OF TECHNOLOGY SYDNEY)

Re: Alternative Solution submission: Urine diversion toilets (UDT) and sampling system

- **"Evidence the Alternative Solution proposed has been used in other regulated jurisdictions"**

  Two states in Australia have installed UDTs to date.
  In Victoria, approximately 30 Wostman and Dubbletten UDTs are being installed in households in Kinglake as part of a pilot study being conducted by Yarra Valley Water (10 suites installed to date). The toilets are all 'dual' plumbed with urine diverted to on-site (household scale) storage for collection by a sullage contractor and eventual re-use on a local turf farm. The blackwater is discharged to a STEP/STEG system. Greywater is separately plumbed, and treated on site at the household scale for reuse.
  In Queensland, 16 households at Currumbin Eco-village have installed UDTs (Gustavsberg UDT model) recovering urine. Again, there is household scale storage and collection by sullage contractor with the intention of reuse within the Eco-village lands. Blackwater is collected at the community scale, treated by a modified Advantex system, and recycled on-site.

- **"The basis on which this project is given and the extent to which relevant specification or other publications have been relied upon".**

  The project is investigating the feasibility of urine diversion to capture and reuse nutrients, by trialling the necessary technical/material infrastructure (user interfaces, collection, sterilisation, transport and reuse systems) and researching the associated social, EH&S and regulatory issues. If proven feasible, there are significant benefits including significant savings in wastewater treatment costs, reduction in nutrient pollution of aquatic environments, reduction in water consumption, and provision of phosphorus for agriculture in the face of dwindling raw mineral resources of phosphorus[1]. While several trials have been conducted in Europe, it is important to examine the issues particular to the Australian context. This trial is focused on public

[1] Larsen, Tove A., Irene Peters, Alfredo Alder, Rik Eggen, Max Maurer and Jane Muncke. 2001. "Reengineering the toilet for sustainable wastewater management." Environmental Science and Technology 35(9):192A-197A.

installations of UDTs, a marked contrast with both the Eco-Village or utility trials also underway.

Manufacturer's specifications/instructions have been relied upon for the installation of the UDTs, with other literature consulted to reduce anticipated problems. These include GTZ (2010)[2] and also Kvarnstrom et al (2006)[3], which contain advice on plumbing components, inclinations, water seal etc. In addition, in collaboration with Caroma, we are conducting standards testing of each of the pedestals under NATA conditions, and extending to US based standards for toilet performance.

Yours faithfully,

Cynthia Mitchell
Research Director
Institute of Sustainable Futures
University of Technology Sydney

---

[2] Reference: GTZ, 2010. *Technology review on urine diversion components - Overview of urine diversion components such as waterless urinals, urine diversion toilets, urine storage and reuse systems*. Deutsche Gesellschaft für Technische Zusammenarbeit GmbH (GTZ) http://www.gtz.de/en/dokumente/gtz2010-en-urine-diversion-appendix-suppliers-lists-2010-02-17.pdf

[3] Kvarnstrom, E., Emilsson, K., Stintzing, A.R., MJohansson, Jonsson, H., Petersens, E., Shonning, C., Christensen, C., Hellstrom, D., Qvarnstrom, L., Ridderstolpe, P. & Drangert, J.-O. 2006, *Urine Diversion: One Step Towards Sustainable Sanitation*, Stockholm Environmental Institute, Stockholm.

APPENDIX 6 - UTS FACILITIES MANAGEMENT – LETTER OF ACKNOWLEDGEMENT

Facilities Management Unit

UTS
University of Technology, Sydney

27 January 2011
Department of Fair Trading
PO Box 972
PARRAMATTA NSW 2124

Re: Building 10 Alternative solution proposal – urine diversion toilet and sampling system

To whom it may concern,

We, the Facilities Management Unit at University of Technology Sydney (UTS), being the managers of the facilities within Building 10, 235 Jones St, Ultimo, 2007 hereby acknowledge the following:

A submission is being lodged under the "Alternative Solutions" provision of the Plumbing Code of Australia (PCA) for an alternative plumbing solution involving urine diversion and sampling of urine for reuse in agricultural application.

We acknowledge the installation associated with this submission has been installed within our property at the above address and was installed by a licensed plumber accredited to install these works.

We understand the installation is in conflict with the general intent of AS/NZS 3500.2

Yours Sincerely

John Kraefft

Manager, Building Services

UTS:INSTITUTE FOR SUSTAINABLE FUTURES

TRANSITIONING TO SUSTAINABLE SANITATION – A TRANSDISCIPLINARY PILOT PROJECT OF URINE DIVERSION

Appendix 3

Risk Management Plans

Appendix 3(a) – Risk Management Plan for Urine Collection System

RISK MANAGEMENT MATRIX FOR INSTALLATION/OPERATION/DECOMMISSSION OF URINE COLLECTION FROM WATERLESS URINAL TRIAL

	ACTIVITY	INHERENT RISKS/HAZARDS	CONTROL MEASURES	RESIDUAL RISK MEASUREMENT
INSTALLATION	**Manage expectations of neighbours on Level 2 & 3**	• **Reputational risk**	• Identify and manage stakeholder engagement with actors directly involved with the installation site - Level 2 and level 3, building 1 (Science workshop, Central Services, Equity Diversity Unit) • Seek stakeholder input into the installation process	• Likelihood of harm is LIKELY • Consequence of harm is MINOR **MEDIUM RISK**
	Manage odour prevention	• **Complaints from neighbours**	• Plan weekly site inspections • Engage weekly with neighbours in regard to gaining their perceptions of odour on-site	• Likelihood of harm is LIKELY • Consequence of harm is MINOR **MEDIUM RISK**
	Manage capacity of urine tank	• **Overflow of urine tank**	• Installation of Saniflow pumping mechanism with connection and overflow to the sewer set to trigger overflow at 500L of collection • Installation of a two-way diverter to divert urine to sewer when required • Weekly inspections to track urine collection level	• Likelihood of harm is LIKELY • Consequence of harm is MINOR **MEDIUM RISK**
	Manage interference of urine tank during collection process	• **Unexpected impact of tank from vehicles in car park**	• Install locked wire cage 0.5m around collection tank to provide buffer and absorb impact from unexpected vehicle collision	• Likelihood of harm is POSSIBLE • Consequence of harm is MODERATE **MEDIUM RISK**
		• **Tampering of tank/fittings by unauthorised personnel**	• Install locked wire cage to the height of 7ft around collection tank to limit access by unauthorised personnel	• Likelihood of harm is POSSIBLE • Consequence of harm is MODERATE **MEDIUM RISK**
		• **Vandalism**	• Engage with Security (FMO) to monitor installation site for potential vandalism • Limit access to collection tank by installing locked wire cage	• Likelihood of harm is POSSIBLE • Consequence of harm is MODERATE **MEDIUM RISK**

RISK MANAGEMENT MATRIX FOR INSTALLATION/OPERATION/DECOMMISSSION OF WATERLESS URINAL TRIAL

	ACTIVITY	INHERENT RISKS/HAZARDS	CONTROL MEASURES	RESIDUAL RISK MEASUREMENT
OPERATION	**Prevent spillage during urine collection process on-site**	• **Exposure to pathogens**	• Create clear warning signs and install in conspicuous place to limit risks associated with tank puncture • Availability of PPE kit on-site (gloves, goggles, mask) and mandatory requirement of using closed shoes when sampling. • Availability of HAZCHEM spill kit on-site to manage any spills • Mandatory hand washing protocol after sampling.	• Likelihood of harm is POSSIBLE • Consequence of harm is MODERATE **MEDIUM RISK**
	Prevent spillage from unexpected puncture of urine tank on-site	• **Exposure to pathogens**	• Install collection tank encased in metal cage • Install 1100L bund on-site to collect unexpected spillage from tank puncture, sullage truck to pump out urine from bund on day of tank puncture and disinfection of bund after tank puncture and pump out	• Likelihood of harm is POSSIBLE • Consequence of harm is MODERATE **MEDIUM RISK**
	Prevent spillage during transference of tank from collection site to collection vehicle	• **Exposure to pathogens**	• Disconnection/reconnection of collection tank to be managed by instructed project staff only • Transference of tank from site to vehicle to be done by qualified forklift operators only • Installation of dual shut-off valves to prevent urine from urinal to tank • Provide access of PPE kit on-site (gloves, goggles, mask) and mandatory requirement of using closed shoes when sampling. • Provide access to HAZCHEM spill kit on-site to manage any spills • Mandatory hand washing protocol after sampling	• Likelihood of harm is POSSIBLE • Consequence of harm is MODERATE **MEDIUM RISK**

	Empty/maintain tank urine levels when required	• **Exposure to pathogens**	• Installation of two-way diverter to divert urine to sewer when necessary • Installation of Saniflow pump to safely empty tank by pumping tanked urine to sewer when required	• Likelihood of harm is POSSIBLE • Consequence of harm is MODERATE **MEDIUM RISK**

RISK MANAGEMENT MATRIX FOR INSTALLATION/OPERATION/DECOMMISSSION OF WATERLESS URINAL TRIAL

	ACTIVITY	INHERENT RISKS/HAZARDS	CONTROL MEASURES	RESIDUAL RISK MEASUREMENT
DECOMMISSION	**Sanitisation/removal of tank**	• **Exposure to pathogens**	• Discharge excess urine with use of saniflo pump diverting collected urine back to the sewer • Use PPE kit for cleaning tank • Disinfect urine tank with appropriate cleaning agents pumping wastewater back to the sewer	• Likelihood of harm is POSSIBLE • Consequence of harm is MODERATE **MEDIUM RISK**
	Sanitisation/storage of bund	• **Exposure to pathogens**	• Disconnect bund and disinfect on-site (if required) before storage on-site Building 10	Likelihood of harm is POSSIBLE • Consequence of harm is MODERATE **MEDIUM RISK**
	Sanitisation/storage of bund	• **Exposure to pathogens**	• Disconnect bund and disinfect on-site (if required) before storage on-site Building 10	Likelihood of harm is POSSIBLE • Consequence of harm is MODERATE
	Sanitisation/storage of bund	• **Exposure to pathogens**	• Disconnect bund and disinfect on-site (if required) before storage on-site Building 10	Likelihood of harm is POSSIBLE • Consequence of harm is MODERATE

		CONSEQUENCES OF HARM				
		Insignificant	Minor	Moderate	Major	Severe
LIKELIHOOD OF HARM	Almost certain	M	H	H	E	E
	Likely	M	M	H	H	E
	Possible	L	M	M	H	E
	Unlikely	L	M	M	M	H
	Rare	L	L	M	M	H

CONSEQUENCE OF HARM
This is how bad it will be if something does go wrong i.e. the number of people that could be harmed, the severity of injury.
INSIGNIFICANT – No medical treatment required. Minor effects on biological or physical environment.
MINOR – Reversible disability requiring hospitalisation. Moderate, short-term effects but not affecting ecosystem functions.

LIKELIHOOD OF HARM
This is the chance of this harm occurring and is affected by the duration of the activity and its frequency; the number of people doing the activity and the level of exposure to the hazard.

Appendix 3(b) – Risk Management Plan for Sampling System of UDTs

RISK MANAGEMENT MATRIX FOR SAMPLING/COLLECTING/TRANSPORTING URINE FROM URINE DIVERSION TOILETS

ACTIVITY	INHERENT RISKS/HAZARDS	CONTROL MEASURES	RESIDUAL RISK LEVEL
1. Collecting urine sample for external analysis (SWC & UWS)	• Exposure to pathogens, (ingestion, skin contact, inhalation of aerosols &/or liquids) • Spillage of urine • Injury from lifting collection vessel	• Follow safety procedures for operating sampler • Wear gloves, goggles, mask and closed shoes when sampling, (Personal Protective Equipment - PPE) • Mark diversion valves clearly as 'open'/'closed' • Wash hands after sampling • Collect urine on provided shelf	• Consequence of harm is INSIGNIFICANT • Likelihood of harm is POSSIBLE **LOW RISK**
2. Collection of samples for onsite analysis	• Exposure to pathogens • Spillage of urine • Injury from bearing weight during collection	• Wear gloves, goggles, mask and closed shoes when sampling, (PPE) • Wash hands after sampling • Use disinfectant to mop or wipe up any spillage with equipment designated to sampling room • Use shelf provided to collect samples, do not bear weight of vessel during collection	• Consequence of harm is INSIGNIFICANT • Likelihood of harm is POSSIBLE **LOW RISK**
3. Using water quality probe for onsite analysis	• Electrical injuries from using electrical cords/liquids • Injuries from misplaced cords • Exposure to pathogens	• Wear gloves, goggles, mask and closed shoes when sampling, (PPE) • Wash hands after sampling • Electrical equipment must be used close to power • Analysing samples must be done on table provided	• Consequence of harm is INSIGNIFICANT • Likelihood of harm is POSSIBLE **LOW RISK**
4. Storing urine samples onsite	• Spillage • Leakage from vessels • Exposure to pathogens	• Store vessels out of walkway with firmly sealed lids • In case of spillage/leakage, wear gloves, goggles, mask and closed shoes (PPE) for clean up • Wash hands after clean up	• Consequence of harm is INSIGNIFICANT • Likelihood of harm is POSSIBLE **LOW RISK**
5. Transporting urine for use outside UTS	• Spillage during transportation • Injuries from moving/transporting vessels	• In case of spillage/leakage, wear gloves, goggles, mask and closed shoes (PPE) for clean up • Wash hands after clean up • Use correct lifting procedures when moving vessels • Use a trolley from transporting vessels	• Consequence of harm is INSIGNIFICANT • Likelihood of harm is POSSIBLE **LOW RISK**

NEXT STEPS IN DEVELOPING RISK MANAGEMENT PLAN IN ACTION

- Design collection shelf in sampling room to fit collection vessels and reduce potential for injury in collecting urine from sampling system
- Develop PPE Kit with goggles, masks and gloves to be stored hygienically in sampling room for use by samplers
- Designate area in sampling room for storage of on-site samples, clearly mark as designated area
- Design and designate urine sampling table for analysis using water quality probe – situated in close proximity to power outlet

		CONSEQUENCES OF HARM				
		Insignificant	Minor	Moderate	Major	Severe
LIKELIHOOD OF HARM	Almost certain	M	H	H	E	E
	Likely	M	M	H	H	E
	Possible	L	M	M	H	E
	Unlikely	L	M	M	M	H
	Rare	L	L	M	M	H

CONSEQUENCE OF HARM
This is how bad it will be if something does go wrong i.e. the number of people that could be harmed, the severity of injury.
INSIGNIFICANT – No medical treatment required. Minor effects on biological or physical environment.
MINOR – Reversible disability requiring hospitalisation. Moderate, short-term effects but not affecting ecosystem functions.
MODERATE – Moderate irreversible disability or impairment to one or more persons. Serious medium term environmental effects.
MAJOR – Single fatality and/or severe irreversible disability to one or more persons. Very serious long term impairment of ecosystem functions.
CATASTROPHIC – Multiple fatalities

LIKELIHOOD OF HARM
This is the chance of this harm occurring and is affected by the duration of the activity and its frequency; the number of people doing the activity and the level of exposure to the hazard.

RARE – Once every 100 years or more
UNLIKELY – Once every 30 years
POSSIBLE – Once every 10 years
LIKELY – Once every 3 years
ALMOST CERTAIN – Once a year or more frequently