CLOSING THE LOOP:
A SYSTEMS THINKING LED SUSTAINABLE SANITATION PROJECT IN AUSTRALIA

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ABSTRACT

This paper will explain a research project being carried out in Sydney, Australia at the University of Technology Sydney (UTS) highlighting the systems thinking principles and action research methodology being adopted in this project.

UTS is set to participate in an Australia-first research project, led by the Institute of Sustainable Futures (ISF), exploring the use of innovative urine diverting toilets in an institutional setting. A UTS Challenge Grant (an internal grant scheme to promote innovative collaborative research) has been awarded to the project which will enable safe nutrient capture and reuse from urine diverting toilets installed on campus for a trial period.

The Challenge Grant has some enthusiastic industry partners including the local water utility Sydney Water; the sanitary-ware manufacturer Caroma Dorf; the Nursery and Garden Industry Australia; government partners (NSW Department of Health, and City of Sydney) and the UTS Facilities Management Unit. Researchers from the University of Western Sydney and University of New South Wales in Australia as well as Linkoping University in Sweden are collaborators in this research.

Keywords: Sustainability, Systems Thinking, Action research, Urine Diversion

INTRODUCTION

Excessive nutrient loading is one of the most important direct drivers of ecosystem change in terrestrial, freshwater, and marine ecosystems (Millennium Ecosystem Assessment 2005, p. 69). Urine contained in wastewater from sewerage systems is a major source of these nutrients. Wastewater treatment processes for removing nutrients before release or re-use are highly energy and chemical intensive.

At the same time, mineral phosphate rock deposits from which phosphate fertiliser is derived are approaching a peak not unlike peak oil, with known reserves estimated to run out within the next century (Cordell et al. 2009). Lack of availability of phosphorous could lead to insecurity of global food production resulting in hunger, social issues and conflict.

Urine is a potential source of phosphorus, and diverting and capturing nutrients could partially replace mineral fertilisers in agricultural use, as well as reduce the cost of wastewater treatment and reduce negative environmental impacts. Therefore concentrated populations in cities, in particular, offer a rich 'mine' for phosphorus. There are, however, many barriers to be overcome before this resource can be exploited, not the least of which are the social taboos and attitudes towards reuse of human waste.

The pilot project described in this paper is an innovative attempt to trial urine diversion in a university setting in central Sydney, Australia. The project is in its early stages so this paper will focus on how a systems thinking approach has shaped this study – an approach which will be of great interest to this conference.

The paper is structured to describe the project in terms of the four elements that Checkland (2000, p. 821) identifies as generic to a soft systems approach for dealing with complex, real-world problems. They are:

- The perceived problem situation
- The process for tackling the situation
- The group of people involved in the process; and
- The combination of situation, process and people.

THE PERCEIVED PROBLEM SITUATION

The centralised piped sewerage model has provided enormous health benefits that have enabled economic development, and become the dominant paradigm for urban sanitation systems in most parts of the world (and aspired to by countries that do not already have them (UNICEF 2010)). However, in the long term, it rates poorly from a sustainability standpoint. The model relies on large volumes of water, usually of a potable standard, being used to transport waste from cities for resource-intensive sewage treatment, and the misplacement of potentially valuable nutrients as noted above, the latter leading to nutrient pollution in receiving environments or the employment of costly processes for removal. Thus, the well established urban sanitation system is perceived to be the problem situation of interest.

The aim of this project is to explore the range of interdependent factors that can support transitioning towards a more sustainable and resource efficient sanitation system. To create such a shift requires mutually reinforcing institutional and socio-cultural transformations including new infrastructure planning processes; sympathetic regulatory and legal frameworks; altered user practices; and re-cast cultural meanings in the water industry, agricultural and horticultural sectors and beyond. Enabling this change therefore requires partnership and collaboration from stakeholders with a range of disciplinary knowledge and a shared commitment to sustainability and transdisciplinary learning.

A competitive Challenge Grant from the University of Technology Sydney (UTS) (a scheme to provide seed funding to support activities related to high-quality, collaborative cross-disciplinary research that will assist in advancing UTS's vision to be a world-leading university of technology) was secured as funding for the 2 year project.

THE PROCESS FOR TACKLING THE SITUATION

The project will take tangible steps towards closing the nutrient loop by retrofitting a male and female toilet block on the UTS campus with a number of urine diverting toilets and waterless urinals. Urine collected from the installed toilets will be tested as a substitute for phosphate and other fertilisers in a small-scale agricultural trial during the study. Figure 1 shows examples of such toilets.

Image from www.dubbletten.nu

Image from www.caroma.com.au

Figure 1. An example of a urine diverting toilet and waterless urinal

A systems view of the multi-level project and its context (Figure 2) means that the research has several aspects. Several strands have been set up in the project organization to address these aspects.

- A *technology strand* will address the physical engineering and technical issues around designing, implementing and commissioning the retrofit, collecting samples, operating, maintaining and monitoring the technical performance, and implementing the agricultural trials.
- Engagement with a wide range of stakeholders is recognised as critical to the acceptability and ultimate success of the pilot, so *stakeholder engagement* is explicitly targeted, to track and shift attitudes of users of the toilets as well as maintenance and management staff.
- Effective communication is an essential element for engagement, so a research strand specifically focused on *visual communications* for the project has been defined.
- The pilot, like conventional toilets, exists within a regulatory and institutional context that constrains what is possible and what is not. It is critically important to engage with the legal and regulatory frameworks, and the institutional arrangements as they are key enablers or impediments to the kinds of paradigm change that the project seeks to initiate. A *regulations/institutions strand* will address such issues.

- A separate *integration research strand* will focus on integrating the other research strands from a whole of system standpoint.

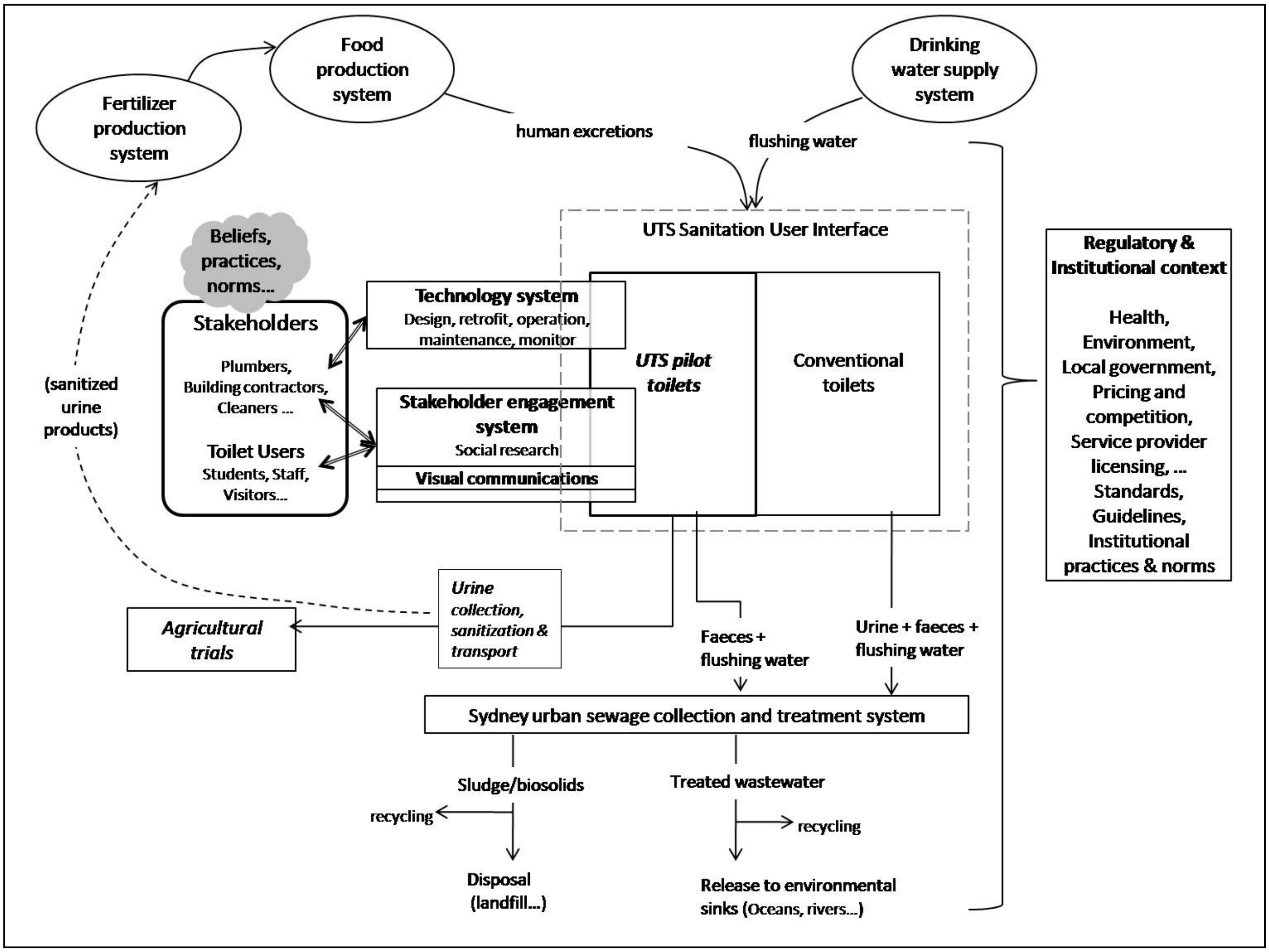

Figure 2. Systems and environment associated with the Pilot

Action research

While urine diversion trials have been tried elsewhere, this study breaks new ground with its coverage of social and regulatory aspects and not merely technological ones. Action research was selected as an overarching methodology or a meta-methodology (Dick 2004), as being particularly appropriate for supporting collaboration and learning for the multidisciplinary team of researchers (discussed next section). The project will also monitor changes in attitude and behaviour of stakeholders. Thus there is an opportunity to use essential elements of an action research cycle – plan, act, observe, reflect and plan for the next cycle – in this research project. According to the current edition of the *Handbook of Action Research* (Reason and Bradbury 2007, p. 4): action research is defined as:

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"… a participatory process concerned with developing practical knowledge in the pursuit of worthwhile human purposes. It seeks to bring together action and reflection, theory and practice, in participation with others, in the pursuit of practical solutions to issues of pressing concern to people, and more generally the flourishing of individual persons and their communities."

This research project intends to use three action research cycles:

Cycle 1 is an investigation cycle to facilitate the emergence of the 'thematic concern' for the project (Kemmis and McTaggart 1988) in discussions with each of the research strands. The researchers plan to draw upon aspects of soft systems methodology to inform the detail of their actions. A root definition for the project is expected to be arrived at in this cycle to act as a vision for the project.

Cycle 2 will cover the design, contract and commissioning phase of the project where the technology strand will oversee the design of the retrofitting of the designated toilets, appoint contractors and supervise the installation and commissioning of the toilets. The stakeholder strand will determine the attitude of end-users prior to installation to alleviate any concerns and the regulatory and institutions strand will advise on the regulatory enablers and impediments to the trial.

Cycle 3 will cover operation, monitoring, evaluation and closure of the project. The performance of the toilets, storage and agricultural trials will be monitored and evaluated. End-users' responses to the use of the toilets will be gathered and analysed. The visual communications strand will evaluate the effectiveness of their messages and the regulations/institutions strand will focus on the barriers to closing the loop on nutrient recovery and use. The integration strand will carry out an overall evaluation, decide on new projects extending from this project as well as put together a final report to the stakeholders.

The problem that is being addressed in this project is a complex real-world problem that could be looked upon as a 'wicked problem' (Rittel and Weber 1973). Soft systems methodology (SSM) was developed by Checkland and colleagues (Checkland 1999) as a way of addressing wicked or ill-structured, complex, real-world problems faced in management situations, which have been repeatedly failed by well-established 'hard' systems approaches. This project has therefore adopted many concepts, ideas and tools of SSM.

A recent book by Checkland and Poulter (2006 p. 11) presents a basic version of SSM which includes the following activities:

1. Perception of a problematical real-world situation demanding action to improve it;
2. Creation of models of purposeful activity *relevant* to the situation from different worldviews;
3. A process to explore the models as devices to explore the situation;
4. A structured debate about desirable and feasible changes including a discussion on power issues and considering social norms and values; and
5. Taking action to improve the situation.

A basic version of SSM is shown in their latest book (reproduced here as Figure 3). The actual process of analysis includes the components described in the earlier versions such as drawing 'rich pictures' to clarify the problems as perceived by the stakeholders and developing a 'root definition' based on what the agreed purpose of the system would be.

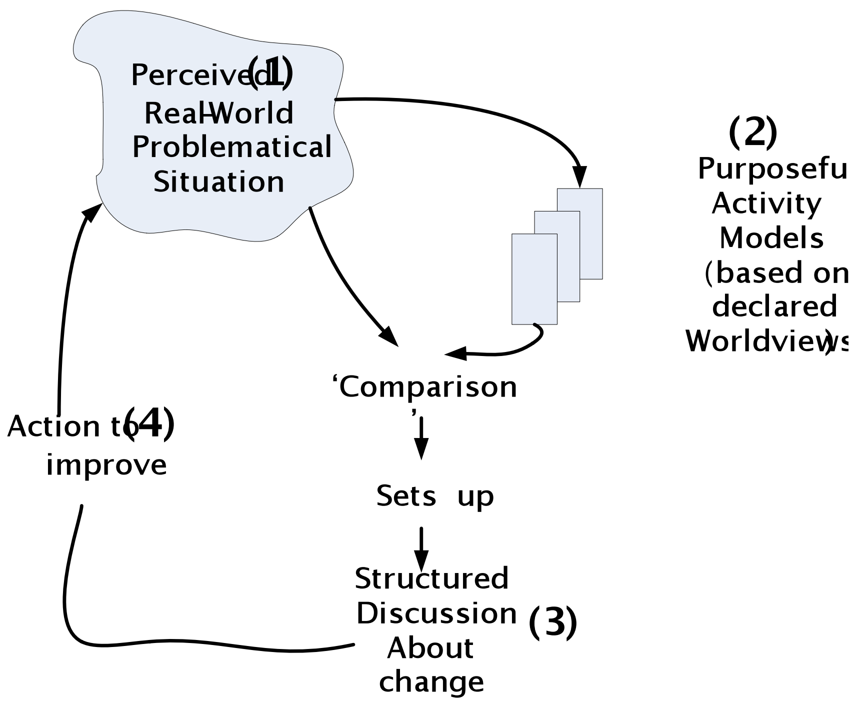

Figure 3 Basic SSM process (Source: Checkland and Poulter 2006, p. 13)

Some components of soft systems methodology have already been applied during the initial meetings of the research team. Among these has been a conceptualisation of the desired project outcomes in terms of an articulation of individual visions – an acknowledgement of the range of worldviews present. It is also anticipated that other thinking tools from SSM will be used, such as compilation of a rich picture of the problematical situation based on stakeholder interviews, and formulation of root definitions of the problem to be addressed based on the CATWOE mnemonic (Customers, Actors, Weltanshauung (worldview), Transformation, Ownership and Environmental constraints) advocated by Checkland and his associates (Checkland 1999, pp. 225-227).

THE GROUP OF PEOPLE INVOLVED IN THE PROCESS

For the sake of clarity in this paper we have interpreted this group to mean the research team, the group of people seeking to take purposeful action to improve the problematic situation, as distinct from the 'stakeholders' who are the subject of our social research noted in the previous section.

The project is being led by researchers at the Institute for Sustainable Futures (ISF) at UTS with a passion for transitioning to sustainable futures in general, and sanitation and phosphorus futures in particular. They invited partners with relevant disciplinary perspectives, knowledge and similar commitments to sustainability from within UTS, other local universities, industry and government, as well as an international expert to play the role of a strategic advisor.

Partnerships with UTS faculties Engineering and Information Technology (FEIT) and Design, Architecture and Building (DAB), bring a combination of experience in technical engineering, project management, stakeholder engagement and visual communications expertise. An academic from the University of Western Sydney (UWS) will collaborate closely with UTS visual communications experts to bring a design focus to the visual communication strand, and collaborate on student research projects. A specialist in water law as it relates to urban wastewater systems, from the University of New South Wales (UNSW), will lead the research strand on regulatory and institutional issues.

An academic expert in agriculture and farming systems from UWS will provide the facilities and carry out the testing and trialling of urine as a phosphorus source. A soils and nutrients specialist from the national nursery and garden industry association will collaborate closely in these trials.

Sydney Water Corporation, the local provider of water supply and wastewater services has a keen interest in the research and has committed funds and personnel to the project. Caroma Dorf, the leading manufacturer of Australian toilet hardware, is contributing its significant experience in the end-user interface to advise on design, installation and monitoring, as well as providing waterless urinal hardware.

Partners from government include a health regulator and a representative from the local government authority City of Sydney.

UTS's Facilities Management Unit is also an active participant that has committed time and funds towards the installation of capital works.

THE COMBINATION OF SITUATION, PROCESS AND PEOPLE

The interaction of the problematic situation, process and people has led to a series of research questions of interest to each research team member from the perspective of his or her particular affiliation and role. For example, team members with teaching commitments have integrated student research projects into the program, at the same time opening up this research space to further research and practice.

This has been presented below in terms of the stakeholders that the project will engage with.

The key stakeholders in the project include: staff and students of, and visitors to, UTS; cleaners; building managers; toilet and plumbing manufacturers; engineers; plumbers; scientists; institutions which engage in sewage management, such as Sydney Water; the agricultural and horticultural industries; interior designers and architects; bathroom product companies, e.g. manufacturers of odorizers; and the central management of UTS.

The following description takes each stakeholder and highlights how they may potentially engage with the pilot, pointing out where it is possible/likely that different stakeholders could have conflicting or aligning interests.

Staff, students and visitors as users: The staff, students and visitors are key stakeholders because they will be the people who actually use the urine diverting toilets. Hence, it will be necessary to provide sufficient encouragement for them actually to use the alternative toilets rather than the traditional ones. It will also be important to monitor that use. One key factor, alluded to in the literature, is that men will need to sit to urinate, rather than stand (Lienert and Larson 2010), if they are to use the alternative toilet properly. If saving flushing water is to be an objective, after urination, women will need to place their toilet paper in a separate receptacle rather than in the toilet bowl itself. Disabled users' experiences will also need to be monitored and analysed as will that of any children who use these toilets. It is possible that the interests of user stakeholders may intersect or clash with those of cleaners, in particular. This issue is discussed briefly below. User stakeholder interests may also connect with those of interior designers and architects, for example, who will be concerned to make the space in which the alternative toilets are housed both functional and aesthetically pleasing.

Students as educators and facilitators: Several student-based projects are planned to support the pilot program. Engineering students at UTS are currently investigating detailed site assessments and identifying technological specifications for the installations. UTS and UWS students working on visual communication methods and contemporary design practices are creating resources aimed at informing other user stakeholders and the community more generally about the aims and objectives of the pilot. Student-based projects are also aimed at specifically raising consciousness about phosphorous collection and use along with the importance of urine diversion as an alternative phosphorous source, hopefully assisting to avert a phosphorous crisis.

A student-based project, at the UNSW will involve the examination of some of the legal and regulatory barriers to installing and maintaining urine diverting toilets.

The student-based projects are intended to build on the technical capacity and values of the industry partners involved with the research and enhance their capacity for innovation. This research synergy will make a positive contribution towards the education of tomorrow's industry professionals and provide them with direct exposure in involvement with real issues facing industry.

Cleaning staff: We anticipate that the effectiveness of both the pilot itself and its wider application in the community will be linked to the experience of the staff who are responsible for cleaning the urine diverting toilets. Special biodegradable cleaning chemicals are needed, to avoid contamination of urine that might prevent its application in agriculture. Because cleaning staff will be required to use special cleaning chemicals and employ different cleaning procedures to urine diverting toilets compared to traditional toilets, engagement with this stakeholder group is seen as critically important. This group, if successfully engaged, may also provide valuable observations, monitoring and feedback.

The interests of cleaning staff as stakeholders also involve questions of risk management and industrial, health and safety issues. For example, they may perceive a greater risk in cleaning an alternative toilet as it is unfamiliar. The time it takes to clean the alternative toilet may also involve an increased workload, leading to a range of associated industrial and employment issues which will need to be canvassed and addressed.

Building managers: The manager of the building(s) in which the urine diverting toilets are installed is another stakeholder.

As with many novel installations a fascination with use and abuse may develop. Hence building managers will play a key role in ensuring that the alternative toilets do not become the site of vandalism or misuse. Building managers will also be important as part of the use monitoring process and they will be relied on to report breakdowns and problems. Their ongoing engagement will be crucial.

Toilet and plumbing manufacturers: Toilet and plumbing manufacturers (such as research collaborator Caroma Dorf) are key stakeholders at the user interface of the technology that lies at the heart of the pilot. While urine diverting toilets are not currently manufactured locally, the research can influence whether they will be in the future. Of particular interest to these stakeholders will be the question of (a) user attitudes and (b) institutional (e.g. central university management) attitudes, because both will impact on the viability of manufacturing urine diverting toilets. Put simply, even if urine diverting toilets prove technically effective in the capture of phosphorous they are unlikely to be manufactured if people find them distasteful or difficult to use. The market for them will be too uncertain.

Engineers, scientists and plumbers: Technical experts such as engineers, scientists and plumbers play a significant stakeholder role because they are responsible for the installation and maintenance of the alternative toilets, piping, and collection and testing tanks. Struvite (a phosphorus compound) precipitation is a particular issue, leading to blockages of urine pipes and needs to be monitored and managed.

Sydney Water: Sydney Water – an agent of change in water use and a wastewater service provider – is both a collaborator and a stakeholder in this pilot. It brings a wealth of experience in encouraging the uptake of new technologies such as dual flush toilets and reduced water consumption showerheads. It is anticipated that there will be a sharing of this knowledge, particularly with student educator stakeholders, who are working on visual communication methods and contemporary design practices. As a water service supplier it is also interested to understand the water saving potential of urine diverting toilets. If these toilets represent the next wave of sanitation development, Sydney Water will be very interested to observe how that may impact on its operation in terms of the implications for its existing sewerage infrastructure, and other regulatory obligations.

A further point of intersection exists between Sydney Water, in its capacity as a sewerage/wastewater service provider, and other stakeholders, such as UTS's central management. To explain, if the pilots are successful, it may be that organisations and institutions (such as UTS or the owners of large office/residential blocks, for example) might choose to separate urine onsite and then send it to collection points where it is treated for its phosphorous content. Presumably logistics and economics will help determine how such decisions are made and whether the owners of the site where the urine is collected undertake such processes themselves or employ the expertise of third party companies. In either event, such approaches may largely by-pass the services of Sydney Water, a fact which may, in turn, have fiscal implications for that institution in terms of erosion of its customer base. A similar issue has been the subject of discussion in the context of recycled water which has been manufactured from sewage. In that context a related question has been who, if anyone, owns the sewage in the first place? Or put another way, is there property in sewage? (Gray and Gardener 2008; Gray 2008) Such a question would appear to be equally applicable in relation to urine itself.

The agricultural and horticultural industries: World food and fibre demand, crop production and fertiliser use is driven by global population and economic growth. Global population, projected to surpass 9 billion in 2050, will place considerable pressure on agricultural and horticultural production systems (United Nations, 2009). In order to meet the food and fibre needs to sustain this growth, farming systems will need to become more efficient in what they do while enhancing productivity in a sustainable business environment. Environmental pressures including drought, climate change and variability and natural resource management will also play a pivotal role in sustaining growth of these industries.

In Australia, production systems will likely satisfy food and fibre demands by using best management practices such as Nursery Industry Accreditation Scheme Australia (NIASA) Best Management Practice guidelines or the Enviroveg Program for vegetable growers. A key element of these guidelines will be improving nutrient use efficiency rather than relying on fertiliser inputs. Urine diversion is of significant interest to these industries due to its characteristics and its potential to minimise fertiliser inputs and improve the fertility of soils and growing medium used in crop production. These characteristics include the high concentration of readily available nitrogen, phosphorous and potassium. The fertilising effect is also reported to be similar to that of nitrogen-rich inorganic fertiliser (Kirchman and Petterson, 1995).

Interior designers and architects: These stakeholders are crucial to transitioning alternative toilet technologies into the commercial and domestic sectors. They will play a major role in technology uptake and will be instrumental in the development of new sociologies of the bathroom. In that regard we have already witnessed a shift from bathrooms as utility spaces devoted to cleanliness (and which after the 1920s included inside toilets), to spaces of pampering and luxury (Davison 2008). It is possible that there may be a shift to incorporate a moral and ethical element in the next iteration of the sociology of the bathroom: an element which may involve 'greening the bathroom'.

Bathroom consumer product companies e.g. manufacturers of odorisers: The interests of this stakeholder group are likely to align with many of the interests of the interior designer and architect stakeholders. It is anticipated that both groups will be concerned with the aesthetics and social aspects of the operation of the urine diverting toilets in the context of the bathroom, the building as a whole and the wider environment. It is also anticipated that there would be a nexus between the interests of this group and user stakeholders as well cleaner stakeholders.

The Central Management of UTS: One aspect of the relationship of this stakeholder to the pilot has been discussed above, in the context of alternative waste (water) service provision. However, the UTS Central Management's interests extend beyond that issue. UTS is implementing a new campus masterplan which is underpinned by sustainability principles. The research will create valuable information that can be applied to other innovations being considered in the masterplan. For example, UTS will be concerned with issues including service provision, cost effectiveness and uptake rates. It will also be concerned with satisfying any legal obligations that fall to it in terms of health related compliance issues and approval/consent issues for the operation of a sewage management facility, including backup service arrangements.

CONCLUDING REMARKS

The project is now in its investigation phase, the first action research loop. Several student projects, especially in engineering and visual communications have already started. Meetings have been held with all the strands to ascertain their key concerns. A project kick-off meeting has been held with key stakeholders and their vision for the end of project has been captured to ascertain what success will mean to each one of them. This has resulted in very interesting discussions. A STEEP (Social Technical Environmental Ethical and Political) analysis has been carried out. A collaborative platform and repository on a website has been set up for the researchers to work together as they are geographically dispersed. A task analysis of how people use toilets is planned to understand issues that may come up before the new toilets are installed.

This project's commitment to a soft systems approach means that it is an investigation of the feasibility and desirability of urine diversion as a potential way of improving the sustainability of urban sanitation systems by closing the nutrient loop. While it can be argued that urine diversion makes good sense from a thermodynamic standpoint, the experimentation with an actual installation from a whole of system and lifecycle perspective might reveal tradeoffs (for example, costs) that may show that it is not feasible in practice – or that this socio-technical innovation is not desirable within the current socio-cultural or institutional context. While the team hopes that they will secure additional funds when the tenure of the current funding expires, and move to further phases of the research, funds are also being set aside for possible decommissioning, should this become necessary from the learning outcomes of the project.

A transdisciplinary approach is often required to address complex problems in relation to sustainability issues that infringe on social and cultural issues as there is no ready-made and acceptable solution. The problem being addressed by this project is socio-culturally complex and, therefore, the effectiveness of approaches and methodologies used during this project has implications beyond sustainable sanitation. In particular, the effectiveness of systems thinking approaches and action research as a meta-methodology to find viable solutions will be tested during this project. At this initial stage everyone involved in the project seems very enthusiastic about their contribution even though some aspects of this research could be looked upon as taboo topics. The real test for this project will come in the next phase when people actually start using the urine diverting toilets and judge whether it is a feasible and desirable way to adopt a change in their attitudes and practices in order to contribute to a more sustainable world.

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