EMERGING PARADIGMS IN THE REUSE OF DOMESTIC WASTEWATER

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I, Gregory Mark Priest, declare that the information contained in this dissertation is the result of my own research unless otherwise cited.

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ABSTRACT

Water is a key yet limited resource in Australia. With the threat of water shortages in Western Australia becoming increasingly important, there is a great need to develop strategies to sustainably manage this resource. Conventional methods of addressing water shortages include the development of new supplies and use of expensive engineering processes. Alternative sustainable options are available from a demand side, including implementing water saving technologies and wastewater management.

The approach to water supply and disposal in developed nations is generally governed by a centralised strategy. This process often results in water being used at an unsustainable rate and disposed of in a wasteful manner. Traditional disposal methods combine all domestic wastewater for treatment and disposal. This is often an expensive undertaking, not only financially but also in terms of energy consumption and environmental impacts. The act of disposing of treated wastewaters to the environment prevents the reuse of the constituents of wastewater.

The reuse of domestic wastewater provides an opportunity to aid water conservation. Reuse of both "blackwater" (toilet wastewater) and "greywater" (wastewater from laundry, bath/shower and kitchen) has successfully been

implemented in Australia and become accepted methods of water and nutrient reuse. In the last decade, another option to recycle wastewater has become popular in Europe. This is the separation and reuse of urine. Benefits obtained from these processes include water conservation and nutrient recycling, but also reduced energy consumption and protection of effluent receiving waters.

Domestic greywater has great potential for reuse in Western Australia. Regulations have recently been relaxed to enable greywater to be reused, after on-site treatment, on domestic gardens. Greywater is the largest in-house wastewater stream, therefore large volumes are available for garden irrigation. The demonstrated success of domestic greywater reuse provides the impetus to promote and implement other forms of domestic wastewater reuse. Similar to greywater reuse, the reuse of blackwater has been successfully demonstrated in Australia, most commonly on a medium-large scale (e.g. community level), but also at the individual domestic scale. Domestic blackwater reuse only awaits approval from the regulatory authorities to make it possible.

Although urine constitutes only 1% of the total domestic wastewater stream it contributes up to 80% of Nitrogen and 60% of Phosphorus found in the stream. Separating the urine either at the toilet, or immediately after flushing, enables the urine to be reused via agricultural or horticultural irrigation. Due to the high concentrations of nutrients, urine can be an effective plant fertiliser, approximately equal to that of a chemical fertiliser. The challenge is to integrate these technologies and practices to provide a method of total domestic wastewater management and reuse.

In order to implement domestic wastewater reuse the State Government and the Regulating Authorities must shift from focussing on conventional water conservation measures to examining the emerging paradigms.

PAPERS ARISING FROM THIS DISSERTATION

Conference Papers and Presentations

Priest, G., Byrne, J., Anda, M., Mathew, K. and Ho, G. (2002) *On-site Domestic Greywater Treatment Systems in Western Australia- Opportunities and Limitations for Landscape Irrigation,* International Water Associations Fifth Specialist Conference on Small Water and Wastewater Treatment Systems, 24th-26th September 2002, Istanbul, Turkey.

To be published and presented:

Priest, G., Byrne, J., Anda, M., Mathew, K. and Ho, G. *Developments in On-site Domestic Greywater Reuse in Western Australia* Water and Wastewater: Perspectives of Developing Countries, New Dehli, India.

Priest, G., Anda, M., Mathew, K. and Ho, G. *Domestic Greywater Reuse as part of a Total Urban Water Management Strategy*, Australian Water Association, 20th Ozwater Convention and Exhibition, Innovations in Water, 6-10 April 2003, Perth, Western Australia.

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INTRODUCTION

The approach to water supply and disposal in developed nations is generally governed by a centralised strategy, with water and wastewater distributed and collected via large-scale piping networks, governed by distant agencies. This process often results in water being used at an unsustainable rate and disposed of in a wasteful manner.

Traditional disposal methods combine all domestic wastewater for treatment and disposal. This is often an expensive undertaking, not only financially but also in terms of energy consumption and environmental impacts. In addition to those costs, this disposal method also has a range of opportunity costs, that is, missed opportunities. The act of disposing of treated wastewaters to the environment prevents the reuse of the constituents of wastewater. Australia currently wastes 86% of its effluent water, foregoing a great opportunity to aid in the sustainable management of water resources (Dillon, 2002).

1.1 NEED FOR STUDY

Much research has been undertaken in the field of implementing sustainable technologies to treat and reuse the widely recognised wastewater fractions of “blackwater” (toilet wastewater) and “greywater” (wastewater from laundry, bath/shower and kitchen). Although there remains room for more development in that field, a push is occurring to look at the wastewater stream in a further fractional manner. The emerging manner of viewing domestic wastewater is in terms of the separate fractions of blackwater, greywater and also “yellow water”, the urine component.

Separation and reuse of urine has become an accepted (and successful) process in many Northern European countries, however, little study has been conducted in Australia on the subject. As the management of our wastewater can aid in water conservation, study on innovative wastewater technologies is required in Australia.

Water is a key yet limited resource in Western Australia. When viewed in terms of the “triple bottom line” factors, the threat of unsustainable water consumption is magnified. Management of this valuable resource is not only a natural resource management and environmental issue; it is also an important economic issue, with significant social implications. This emphasizes the need for careful management of water resources in countries with water supply issues, such as Australia.

With the threat of water shortages in Western Australia becoming increasingly important, there is a great need to develop and implement water saving technologies, such as yellow water, greywater and blackwater recycling in Australia. Benefits obtained from these processes extend from water conservation to reduced energy consumption in wastewater transport and treatment to reduced waterway eutrophication due to reduced use of chemical fertilizers.

The urine separation process is an emerging paradigm in wastewater disposal, treatment and reuse. The separation of urine is not a new process; many cultures worldwide have practised, or continue to practice, separation for ease of disposal and often, reuse (LCS Promotions, 2000). Unfortunately the introduction of Water Closets as well as the use of chemical plant fertilizers has significantly reduced the value of urine (la Cour Jansen, undated). The urine separation process is becoming increasingly popular in Europe, where much of the study on the process is also taking place. The demonstrated success of the process in Europe indicates it also has great potential for implementation in Australia and the wider Asia-Pacific region (Jonssen, 2001). Urine separation has a wide range of benefits, and has the potential to make a significant contribution to sustainable development (Matsui *et al*., 2001).

The process involves, as the name implies, separation of urine from the general wastewater stream, carried out by installation of toilet systems that enable separate collection of faeces and urine. Urine constitutes only 1% of the total household wastewater stream, yet it is the largest contributor of nutrients. Up to 80% of Nitrogen and 60% of Phosphorus in wastewater is from the urine portion (Jonssen, *et al*., 1998). Separation therefore provides an excellent opportunity to reduce impacts such as eutrophication, as well as provide a number of reuse opportunities through reuse of nutrients and the liquid component (Otterpohl, 2000).

Great potential exists to reuse the nutrients available in urine for fertilizer application in Australian horticulture and broad-acre agriculture. Urine separation can also occur without reuse. Depending on technical limitations and prevailing attitudes towards reuse, the urine can be separated for separate treatment, reducing costs and time when compared to treatment of mixed wastewater.

1.2 LIMITATIONS

This study aims to address the management of wastewater produced in a domestic environment. Reuse of wastewater by industry is increasing in Western Australia; however, this wastewater is provided by large wastewater treatment plants or is produced by internal industrial processes. Due to the vast differences between the characteristics of wastewater from these sources and domestic wastewater, only domestic wastewater will be considered.

Much research information gathered regarding urine separation is specific to European experience. Although great success has been achieved with implementing and integrating the urine separation process, this may not necessarily readily transfer to Australia.

This dissertation was therefore limited to examining European processes and programs and drawing conclusions for Australia.

The benefits are that Australia (esp. Western Australia) is currently in great need of new water conservation technologies, and the public has demonstrated that it is committed to water conservation.

1.3 OBJECTIVES

The objective of this study is to address the sustainability issues related to wastewater treatment, disposal and reuse. The study will focus on how the emerging paradigm of urine separation and reuse can be integrated into a sustainable domestic wastewater management plan that also includes blackwater and greywater.

Therefore the specific objectives of this dissertation are to:

- Examine the potential for Domestic Wastewater reuse in Western Australia, including Blackwater, Greywater and the emerging wastewater stream, Yellow water.
- Examine technologies for implementing reuse of the individual wastewater streams
- Address management and regulatory requirements
- Make recommendations for Domestic Wastewater Management.

1.4 METHODOLOGY AND SCOPE

This dissertation is the result of a desktop study. The project was initiated when it was realised little study has been carried out in Australia in the arena of new domestic wastewater technologies. With the sustainability of water supplies in Australia, and especially Western Australia, currently an issue of great importance, the field of wastewater reuse, which can aid in water conservation, was selected as a further area of focus.

A broad range of alternative sustainable wastewater treatment and reuse technologies is available in Australia, however, new developments elsewhere in the world have had little exposure in the country.

The emerging practice of urine separation and reuse, a common technology in Scandinavia, was identified as a technology possessing great potential for implementation in Australia and therefore was selected as the focus of the investigation. It was also decide that consideration of the whole domestic wastewater stream was required, as this then enabled recommendations for 'Integrated Domestic Wastewater Management' to be made. The dissertation therefore includes greywater and blackwater reuse within the research.

The research process involved a literature review of each of the wastewater fractions' characteristics, treatment technologies and reuse processes.

The dissertation reviews the domestic wastewater stream in terms of opportunities for reuse and the technologies that are employed to implement reuse. The final product is a plan for sustainably managing domestic wastewater, employing up-to-date technologies and processes.

The dissertation firstly provides some background to the water supply problem in Western Australia. Chapter 2 introduces the domestic wastewater stream and reviews the current wastewater management methods. The following sections then discuss how the emerging paradigms in domestic wastewater reuse can aid in water conservation and achieving sustainable development. This involves the examination of the individual fractions of domestic wastewater, how they can be separated, treated and reused.

1. Yellow water (Chapter 3)
2. Greywater (Chapter 4)
3. Blackwater (Chapter 5)

In Chapter 6 recommendations for Integrated Domestic Wastewater Management (including reuse of the wastewater streams) are made. The recommendations integrate information gathered from the proceeding three chapters to aid in achieving sustainable management of each of the components of the domestic wastewater stream.

The dissertation then examines recent developments in the State with regards to water and wastewater management, and looks at some of the relevant regulations governing wastewater management in the State. Chapter 8 addresses some of the constraints identified by the research in the reuse of domestic wastewater, also identifying further areas of interest and research. Conclusions as to the potential for reuse schemes to be integrated for domestic wastewater management and water conservation are made in the final chapter.

2

BACKGROUND

Sustainable development has variously been defined as " development that meets the needs of the present without compromising the ability of the future generations to meet their own needs" (Bruntland, 1987) and, by the National Strategy for Ecologically Sustainable Development for Australia, as "…using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased" (Commonwealth of Australia, 1992). Water is one such resource, the importance of which can be seen through the extremely broad influence it has in the world, and also the implications of water supply and disposal to ecological sustainable development. This chapter will examine the importance of water conservation in Western Australia and introduce the domestic wastewater stream, including examining the constituents of the domestic stream and the current disposal practices.

2.1 THE NEED FOR WATER CONSERVATION

In recent years Western Australia (WA) has been facing a water shortage crisis, the State is currently threatened with significant problems in ensuring future generations have sufficient potable water resources. The 'water crisis' has become increasingly prominent in the public, as well as the political arena, becoming a contentious issue.

Problems with ensuring a sustainable water supply have come about through a number of factors. A combination of changes in domestic water use practices, reduced inflow to scheme storage infrastructure and future expectations that water use will continue to increase while climate change will reduce supply ability has contributed to creating the problem that now exists.

Water use in the State doubled over the 15-year period between 1985 and 2000, with outdoor water use being the most significant change, increasing by around 50% within that period. Water consumption is further expected to double by around 2020 (Water and Rivers Commission, 2000).

The importance of conservative water use is emphasised by the fact that the State has experienced a 25-year low (below average) rainfall trend, it is predicted that the low rainfall will continue. The annual average rainfall for the South-West of WA is expected to decrease by up to 20% by 2030 and 60% by 2070 (Commonwealth Scientific and Industrial Research Organisation, 2001). It can be seen from Figure 1 below that annual inflow to Perth's major reservoirs has not exceeded the long-term mean since 1975.

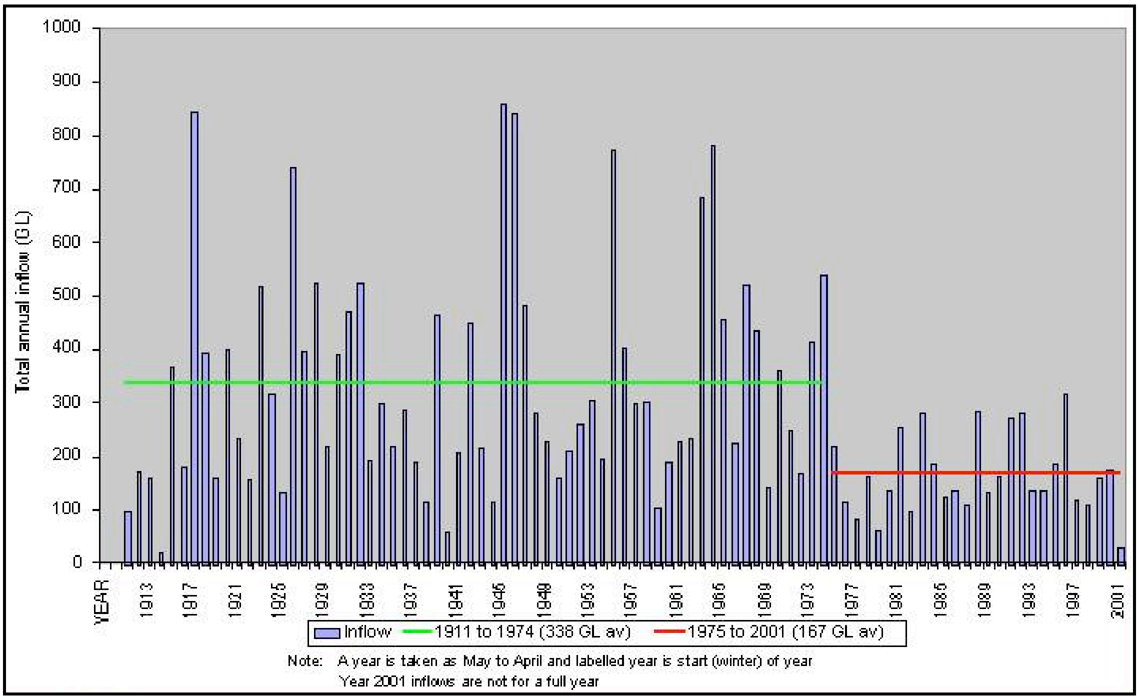

Figure 1 Annual Inflows to Major Perth Metropolitan Reserves (GL) Source: Water Corporation, 2001

The water supply problem has traditionally been addressed by creating more sources of water, typically through more infrastructure (dams, pipelines, bores).

However this is an expensive practice in both financial and environmental terms. More sustainable options are available to aid in water conservation, including improved demand side management (of our scheme and groundwater supplies) and improved management of our wastewater.

2.2 THE WASTEWATER STREAM

The approach to water supply and disposal in developed nations is generally governed by a centralised strategy. Unfortunately, this is not a sustainable process. Worldwide, water is used at an unsustainable rate and is often disposed of in a wasteful and unsustainable manner. Wastewater treatment and disposal relates directly to the sustainability of our water resources, with wastewater a potential resource (via reuse), providing an opportunity to reduce unsustainable consumption of potable supplies.

Developed nations generally employ a centralised strategy to dispose of wastewater. The wastewater stream often includes both household wastewater and stormwater, and is viewed as a problem, rather than a valuable resource. Transport, treatment and disposal methods employed are often unsustainable, requiring high-energy inputs and also result in adverse impacts due to the outputs to the environment.

The dominant practice is to combine all wastewater from households into one stream and transport, via a sewerage system, to a distant plant for treatment and then disposal, often to ocean outfalls and river systems. This process is unsustainable for a variety of reasons. The conventional sewerage system relies on gravity for transport where possible, however, pumping is required to move the wastewater when the landscape doesn’t allow for gravity flow. Such systems are unsustainable due to a combination of the operation energy requirements, infrastructure and maintenance costs. In many cases the systems are additionally unsustainable due to the treatment processes and the final effluent disposal methods (UNEP, 2002).

Figure 2 below demonstrates the typical flow of nutrients in a developed city. It can be seen that the process is a linear flow of nutrients from source to consumers to disposal to the environment, unlike the cyclical process that occurs in nature.

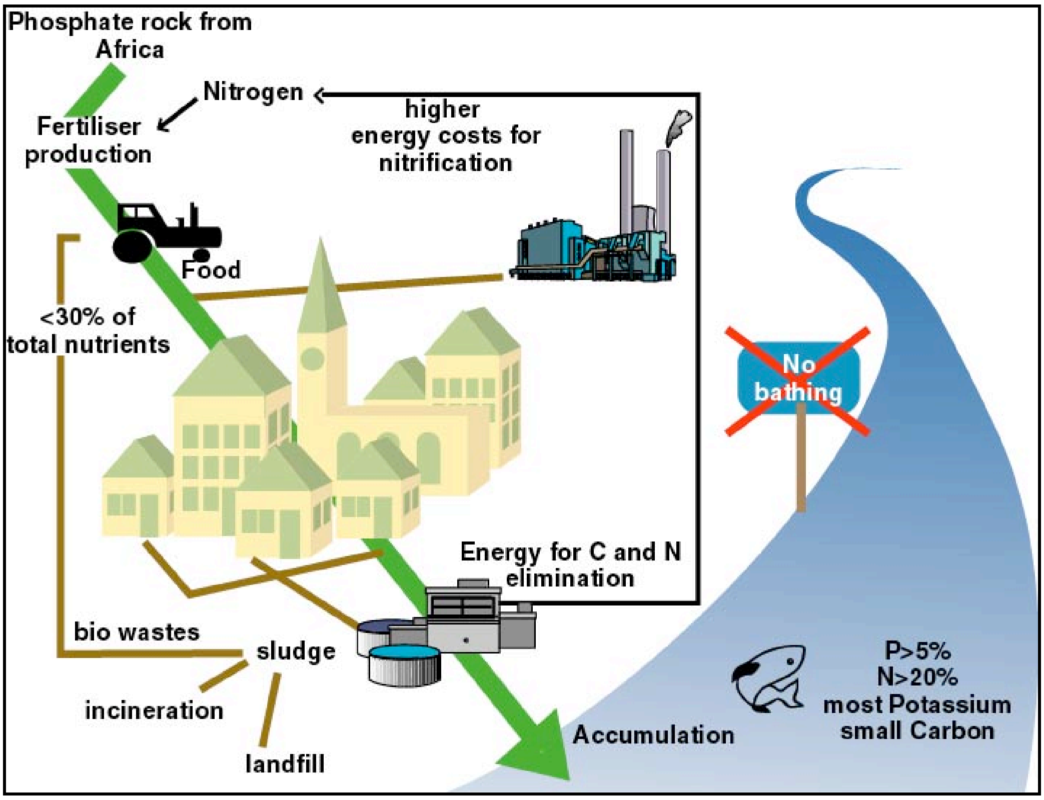

Figure 2 Current unsustainable wastewater management practice, exceeding the natural purification capacity of the ecosystem (Lange and Otterpohl, 1997).

Household wastewater consists of two main streams, possessing different characteristics (see Figure 3). Toilet wastewater, termed 'blackwater', contains high concentrations of nutrients (nitrogen, phosphorus and potassium) and is the fraction that contributes most of the dangerous pathogens present in wastewater. Wastewater from the laundry, bath/shower and kitchen is collectively known as 'greywater'. Greywater, the largest stream by volume, contains low concentrations of nutrients, depending on the amount of phosphorus containing detergents used (Jonssen *et al*., 1998), but can contribute grease and solid/particulate matter to the wastewater stream (UNEP, 2002).

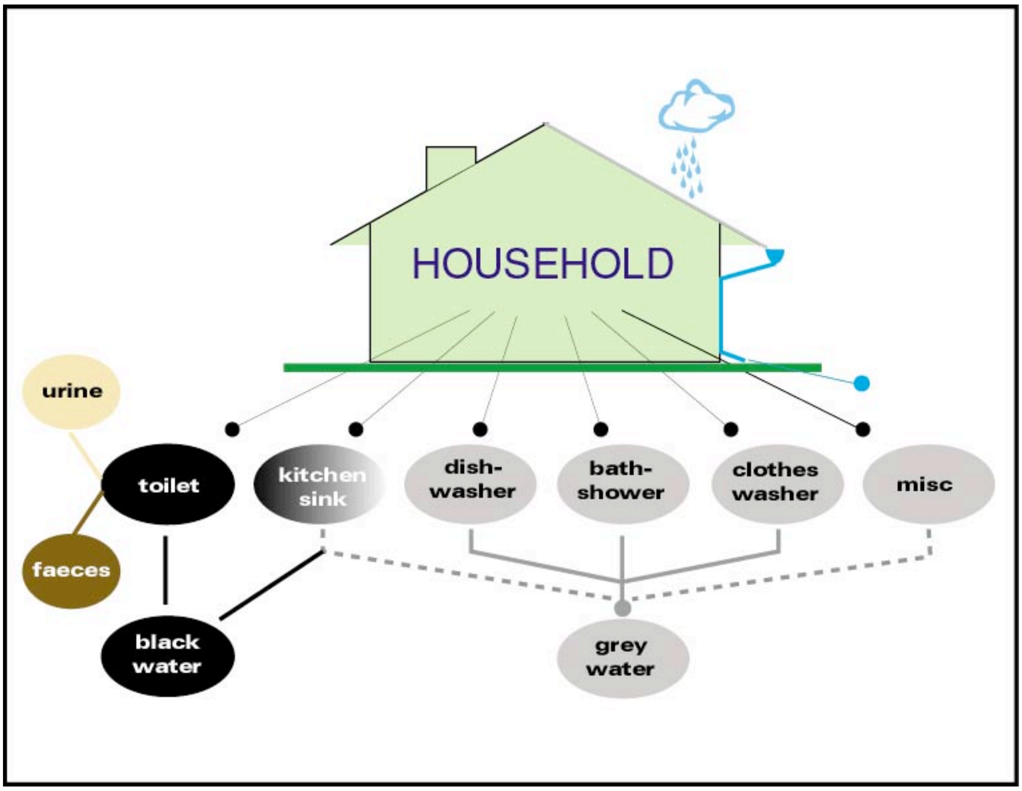

Figure 3 The Domestic Wastewater Streams

The Table below outlines the characteristics of each of the traditional fractions of domestic wastewater. The description includes the main constituents of each streams, what problems can be encountered (and therefore need to be addressed), and potential for reuse.

Table 1 Characteristics of the Wastewater Fractions (adapted from EcoSan, 2002)

Fraction	***Characteristics***
1) Blackwater	
a) Faeces	*Serious hygienic problems* *Contain nutrients and trace elements* *Improve soil structure and increases the water retention potential of the soil*
b) Urine	*Low to no hygienic problems* *Contains the main part of nutrients which can be directly used by plants*
2) Greywater	
a) Shower/bath, laundry	*Low to no hygienic problems* *Biggest fraction with respect to volume* *Contains few nutrients (= easy to purify)*
b) Kitchen	*Low volume* *Contains grease, organic solids* *Treat with blackwater*

The table demonstrates that the wastewater streams (black, grey), and the individual components in each stream (e.g. faeces, kitchen), vary considerably in their contents, and therefore treatment requirements. Further separation could therefore improve the flexibility of reuse. The following chapters address the different streams and their potential for reuse.

3

YELLOW-WATER, SEPARATION AND REUSE

Much research has been carried out to develop sustainable technologies to treat the now widely recognised wastewater fractions of 'blackwater' (toilet wastewater) and 'greywater' (wastewater from laundry, bath/shower and kitchen). Although there is still more work to do in that field, a push is occurring to move further forward and look at the domestic wastewater stream in a more fractional manner. Examining domestic wastewater in terms of blackwater and greywater is now viewed by some as 'narrow'. The wastewater stream can be further broken down to include 'light grey water' (bath, laundry), 'yellow water' (urine) and 'brown water' (faeces). This chapter will consider the urine fraction, including examining the new process of separation, reuse and the technologies.

3.1 THE EMERGING PARADIGM

An emerging paradigm in wastewater disposal, treatment and reuse is the urine separation process. The separation of urine for reuse is not a new process; many cultures worldwide have practised, or continue to practice separation for disposal and reuse (LCS Promotions, 2000). Unfortunately the introduction of Water Closets, as well as the use of chemical plant fertilizers has significantly reduced the value of urine (la Cour Jansen, undated). The urine separation process is becoming increasingly popular in Europe, in particular, the Scandinavian countries, where much of the study on the process is also taking place. The demonstrated success of the process in Europe indicates it also has great potential for implementation in Australia (Jonssen, 2001). Urine separation has a wide range of benefits, and has the potential to make a significant contribution to sustainable development (Matsui *et al.*, 2001). The actual process involves, as the name implies, separation of urine from the general wastewater stream, carried out by the separate collection of faeces and urine. As most of the soluble nutrients are found in the urine, this provides an excellent opportunity to reduce impacts such as eutrophication, as well as provide a number of reuse opportunities through reuse of nutrients (Otterpohl, 2000).

The separation and reuse of urine is a significant move away from the existing paradigm previously outlined, in which all wastewater is combined. The traditional view of domestic wastewater being a single entity is now outdated, with the acknowledgement that wastewater consists of a number of fractions. Table 2 below lists the developing classes of wastewater fractions, from the traditional 'classic' wastewater through to the emerging fractions that can be more sustainably treated, including 'yellow' wastewater.

Table 2 The Wastewater Fractions Palette (Henze and Ledin, 2000, in Matsui et al., 2001)

Type	***Content***
Classic	*Toilet, Bath/shower, Kitchen, Laundry*
Black	*Toilet*
Grey	*Bath/shower, Laundry, Kitchen*
Light Grey	*Bath/shower, Laundry*
Yellow	*Urine*
Brown	*Faeces*

3.2 TECHNOLOGIES

In order to understand the urine separation process, two commercial systems will be examined to outline the methods of separation and reuse available. Both systems were developed in Europe and are in use around the World today.

3.2.1 ROEDIGER "NO-MIX TOILET"

(Roediger, Vakuum und Haustechnik, www.roevac.com)
Developed in Sweden, the Roediger No-Mix is one of a range of 'in the bowl' urine separating toilets, the toilet has been designed with a number of aims in mind including;

- Minimise flush water consumption
- Enable reuse of undiluted urine
- Maintain a comfortable, easy to maintain toilet that appeals to people today

The Roediger urine separation system is similar to a conventional flush toilet in appearance and use. The toilet bowl is divided into two collection sections, a conventional outlet for faeces, and another outlet at the front of the bowl for urine collection (see Figure 4). The outlet of the urine collection section is closed by a plug when not in use, but opens when the toilet seat is sat upon, enabling urine to drain away immediately. In this fashion, men must sit down to use the toilet for urination.

The flushing of the toilet is as with a conventional toilet, however, the plug seals the outlet of the urine section once the user has risen, therefore flush water removes the solid waste (faeces, paper), with only a small amount of water entering the urine outlet. The solid waste can be treated via the conventional reticulated sewerage system, or kept on-site for composting/vermi-composting, treated in an aerobic treatment system or a constructed wetlands system.

Figure 4 The Roediger 'No Mix' Urine Separation Toilet, showing the separate collection basins.

In Scandinavian countries urine is collected in tanks placed in apartment basements, or, where property areas permit it, collected in above or below ground tanks that receive urine from one or more households (see Figure 5).

European Union regulations require that urine remain in the tank for a six-month storage period, prior to collection for reuse. Collection is typically carried out by farmers (via truck tankers) and then reused on their fields.

Figure 5 Above ground urine storage tank See Appendix X for further product information.

3.2.2 AQUATRON

The Aquatron is another system developed in Sweden. The system can employ either a conventional toilet (low or normal flush) or a separating toilet such as the Roediger outlined above. The benefits of separating the urine at the bowl is that it is less likely to be contaminated by pathogens and is not diluted by flush water, such as occurs in a conventional bowl. Whether the non-dilution of urine is preferred or not depends on the final reuse method. Separation of the liquids from the solids occurs in an hourglass shaped unit situated below the toilet. The separating unit has no moving parts and relies on the centrifugal force of the fluid after flushing. Solids (faeces, toilet paper) fall through the centre of the separator into a collection chamber (see Figure 6). The collection chamber can be either a composting or vermi-composting unit.

The liquid (urine, flush water) passes through a unit in which it is subjected to Ultra-violet radiation to kill pathogens, the Swedish practice is to then combine this with greywater for disposal via domestic garden soil infiltration. As Greywater reuse has only recently been permitted in Western Australia, it may be difficult to get domestic urine reuse permitted by the Authorities. Due to the soil types on the Swan Coastal Plain (highly leached, low water holding capacity) the application of nutrient rich wastewater may not be advisable, as this may result in groundwater contamination and/or eutrophication of waterways. Mixing of greywater and urine has been termed 'Designer' greywater, because nutrient levels can be tailored to desired levels by altering concentrations. Where urine is combined with greywater containing 'normal' levels of phosphorus (from detergents containing P) the resulting nutrient concentrations have been found to be ideal for use as plant fertiliser (West, 2001).

The Aquatron provides a very flexible system for alternative methods of treatment and reuse, with a number of diverse range of wastewater treatment configurations possible. See Appendix 1 for further product information

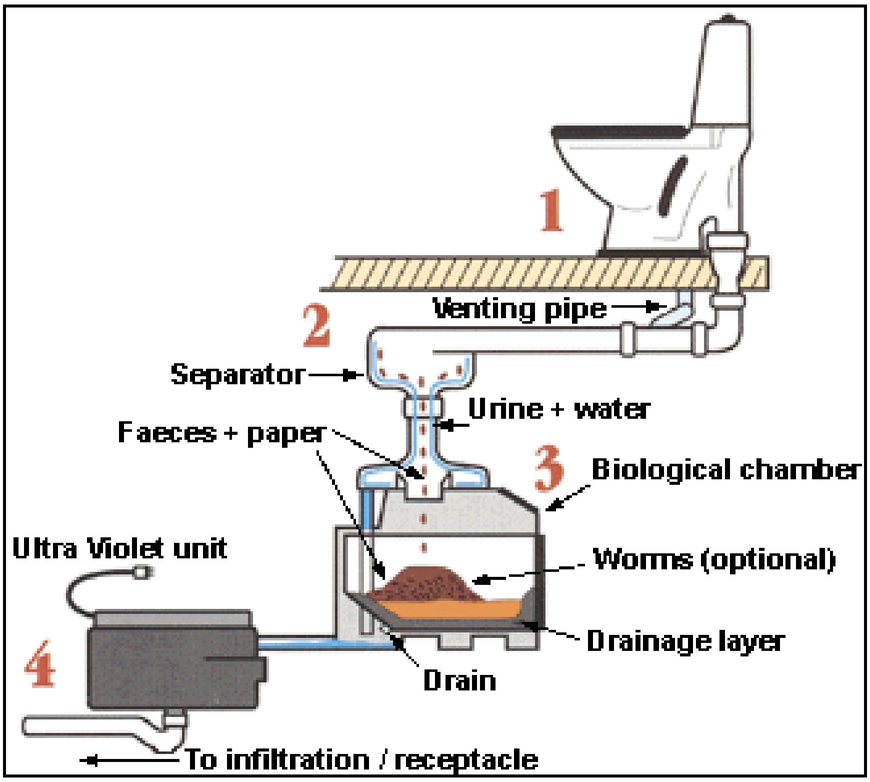

Figure 6 Aquatron System

3.3 ADVANTAGES OF URINE SEPARATION

The urine separation process provides a sustainable option for wastewater disposal and reuse. A wide range of benefits can be obtained through removing urine from the general wastewater stream and reusing it.

The benefits of urine separation begin at the toilet bowl. A dual bowl system uses less water for flushing, therefore conserving water resources while also reducing the volumes to be transported, treated and disposed of. The separation system uses only 0.1L to flush the urine, a reduction of around 24L per person per day, in comparison to standard toilets (Jonssen *et al.*, 1998). This equates to energy conservation through reduced pumping costs and a reduction in the levels of wastewater and nutrients requiring treatment.

Urine constitutes only 1% of the total volume of the household wastewater stream, however it is the largest contributor of nutrients to household wastewater. (Jonssen *et al.*, 1998). The nutrients in urine include Nitrogen (N), Phosphorus (P) and Potassium (K), which are important nutrients required for plant growth. Worldwide the agricultural industry commonly uses chemically produced plant fertilizers, however nutrients can be successfully recycled from urine for use as a natural fertiliser.

Urine can be a very good plant fertilizer, with plant available nutrients in urine high. Nitrogen exists in a number of forms in urine the most common being ammonia and ammonium. Urea, which is easily taken up by plants, is present in fresh urine, however it decomposes to ammonia and carbon dioxide during storage (Adamsson, 2000). Phosphorus and Potassium can also be successfully used as a component of plant fertilizer, though by weight, they are significantly less than nitrogen (Gray and O'Connell, 2000). They can, however, be similar in effect as chemical plant fertilisers. The effectiveness of nitrogen found in urine is around 90% of that of chemical fertilisers (varying between 70% and >100%), with phosphorus equal to that of chemical fertilisers (Jonssen, 2001).

Urine separation in the toilet bowl makes the reuse of the liquid part of the blackwater stream easier and safer due to the absence of pathogens in urine. The urine portion of excreta is sterile, with faeces being the fraction containing high levels of pathogens. Unfortunately, pathogens, enter the urine through contamination in the toilet bowl, most pathogens die off during storage (Jonssen, 2001). Studies by Tarnow *et al*., (2002) found all pathogenic bacteria were reduced to below the detection level of 10 cfu/ml after less than 20 days of storage. As the urine and faeces come into contact in the Aquatron system, ultra-violet light is employed to kill pathogens in the collection tank.

Lammel and Kirchmann (1995) stated that heavy metals are not present in urine as the liver and kidney remove them, further stating that urine is therefore likely to be more suitable for land application than sewage sludge, which can have heavy metals present. However, Jonssen (2001) and Gray and O'Connell (2000) state that heavy metals are present in low concentrations in urine, which can restrict their application as fertilizers, especially for organic farming. Jonssen (2001) goes on to note that it is important to avoid the use of metals in sanitation systems (i.e. pipes), as urine is very corrosive, enabling metals to enter the urine. Correct design of systems can therefore reduce the presence of heavy metals in urine stream.

The separation and reuse of urine encompasses two strategies to achieve sustainable wastewater management, as determined by Karrman (2001);

1. Handle nutrient-rich flows separately from other waste flows.
2. Recycle nutrients and use energy efficiently.

The implementation of urine separation, in conjunction with an integrated reuse system for other fractions of the wastewater stream has the potential to provide a system that both separates nutrients and enables reuse.

3.3.1 CLOSING THE NATURAL CYCLES

Human urine is the largest contributor of nutrients to the household wastewater stream, contributing between 70 and 80% of nitrogen and 50-60% of phosphorus (Jonssen, H., *et al*. 1998; Karrman, undated). The reuse of nutrients in urine can close the natural nitrogen and phosphorus cycles. The nitrogen cycle is shown below, demonstrating the various forms that exist in nature and how they change while undergoing a number of processes (UNEP-IETC, 2001).

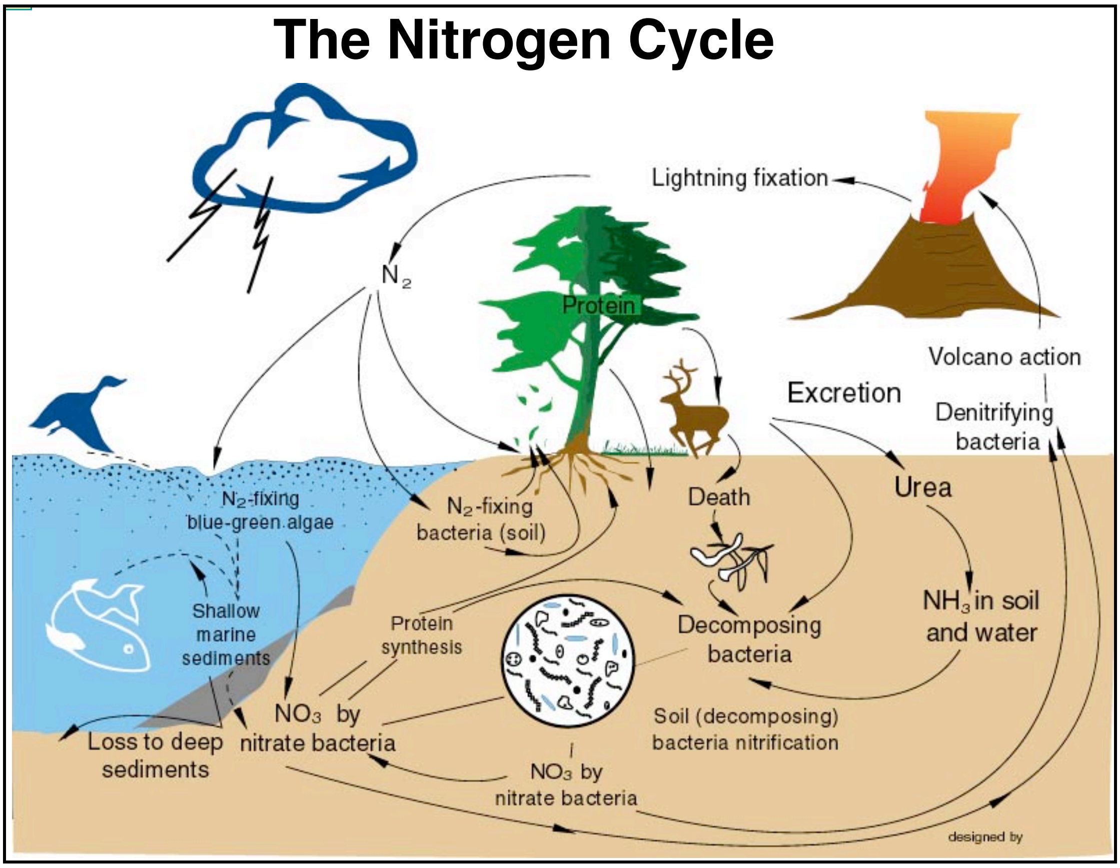

Figure 7 The Nitrogen Cycle (UNEP-IETC, 2001)

3.4 REUSE POTENTIALS

Separated urine can be reused via a number of means. The aim of reuse of urine is to close the nutrient cycle, by enabling the nutrients in urine to be employed by plants. Scandinavian countries most commonly carry out urine reuse by irrigating crops. Although reuse on farms is not strictly 'domestic' reuse, the separation and storage technology is on-site. Limited domestic reuse of urine does occur in some of these countries, with urine being mixed into the greywater stream for on-site disposal via garden irrigation. As mentioned previously though, reuse of wastewaters containing such high nutrient concentrations may not be suitable in Western Australia due to soil types and the risk of ground and surface water contamination. Some local plant species also have low nutrient tolerance levels due to their adaptation to the poor soils of the State (Dept of Health, 2002)

Due to concerns with a lack of knowledge of plant uptake risks, the European Union has restricted the reuse of urine, with no reuse permitted on food crops intended for human consumption (West, 2001b). Currently Norway (not part of the EU) still allows this, however due to the inability to export the products to the European market, also does not practice reuse on food crops, reuse therefore remains to be quite limited. More research is required to determine the agricultural (especially broad-acre) potential of urine-based fertiliser for reuse on the type of crops grown in Australia.

Alternatives in Australia to using urine on food crops include reuse on the extensive tree farms (LCS Promotions, 2000) and the method employed by Sweden, Denmark and Finland, reuse on animal fodder crops. Another potential reuse arena is large-scale horticultural activities such as flower growing and propagation of seedlings. Figure 5 below shows how diverse reuse can be, with simple evaporation (to extract nutrients) through to storage for agricultural type use.

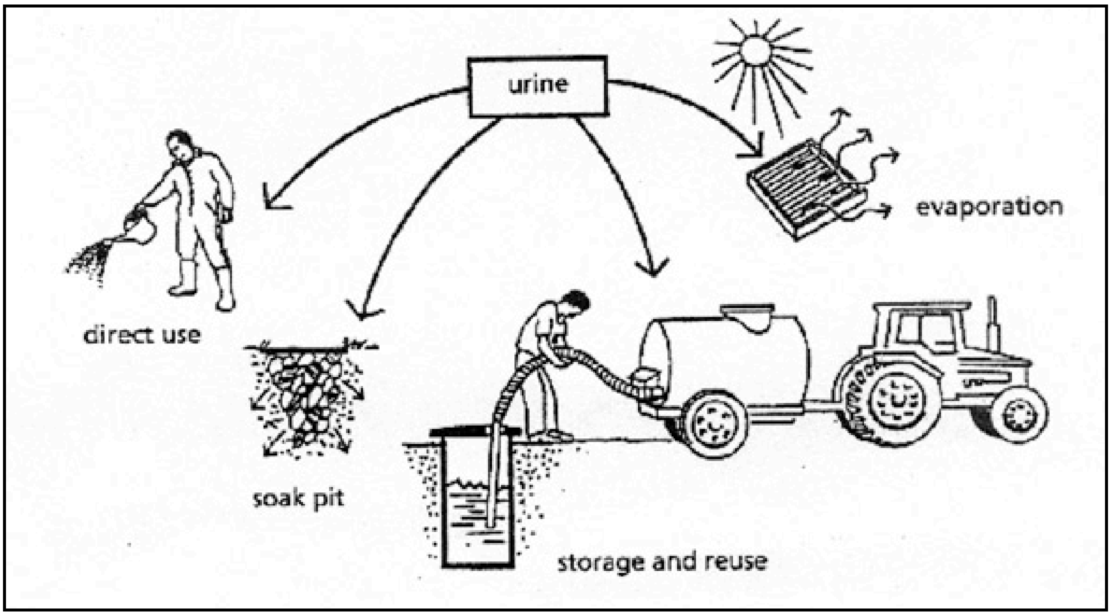

Figure 8 Varying Methods of Urine Reuse

Table 3 below compares the nutrient constituents of the various wastewater fractions (produced per person per year). It can be seen that urine contains by far the greatest proportion of nutrients, while greywater is the most significant in terms of volume.

Table 3 Composition of the Wastewater fractions (Matsui et al., 2001)

	Yearly Loads	Greywater	Urine	Faeces
Volume		25,000-100,000 L/p/yr#	500 L/p/yr	50 L/p/yr
Nitrogen	4.5 kg/p/yr*	3%	87%	10%
Phosphorus	0.75 kg/p/yr	10%	50%	40%
Potassium	1.8 kg/p/yr	34%	54%	12%

*kg/p/yr: Kilograms per person per year
L/p/yr: Litres per person per year

The table below demonstrates the ability of the nutrients found in one persons urine and faeces (in one year) to provide the nutritional requirements to produce around 200 kg of grain (Sundblad and Johansson, undated, cited by West, S. 2001). Australian agriculture consumes high amounts of chemical fertilisers, which could be replaced by the more sustainable source of nutrients found in urine.

Table 4 Nutritional requirements of 200 kg of grain, as supplied by the excrement of one person (Sunblad and Johansson, undated, cited by West, 2001)

Nutrient	Urine (kg/p/yr)	Faeces (kg/p/yr)	Demand of 200 kg Grain
Nitrogen	4.5	0.6	4.5 kg
Phosphorus	0.4	0.3	0.6 kg
Potassium	0.9	0.15	1.0 kg

3.5 ISSUES FOR FURTHER CONSIDERATION

The urine separation process has been studied and successfully implemented for some time in Europe, however, although this indicates that it may be implemented in Australia, it doesn’t guarantee it will be successful. Prior to implementing such technologies, a significant amount of study and groundwork needs to be undertaken

Further areas of study required to ensure the suitability of the process in Australia include the social aspects of the processes of its introduction and the impact of pharmaceutical products and endocrine disruptors in urine.

The most important question with regard to the social aspects is:

What would the Australian response to employing urine separation systems be?

That is, would the Australian community be receptive to the idea of using urine separation systems and the reuse of urine for agricultural purposes. Further areas of interest include determining the response of those that will use the urine as fertilisers (the farmers) and the consumers of products fertilised with urine. Implementing such a technology would require a cultural shift in the household, but also in the agricultural sector.

Winblad (2000) states that social marketing is essential to make urine separation and reuse a success. Jonssen (2001) notes that results of studies on the effectiveness of urine separation in a number of housing districts in Sweden varied significantly. The results indicated that the process was more successful, in terms of proportions of urine and nutrients collected, in those districts where inhabitants chose to install separation systems. The districts that did not voluntarily install systems (such as rental properties) were not as effective at collection. This demonstrates the importance of users being accepting and supportive of the process (la Cour Jansen, undated).

The public may be receptive to the idea, however it is important for the administrating departments to also be supportive. Australian Regulatory departments have been relatively conservative in permitting use of wastewater reuse technologies at the domestic level, although the community has demonstrated support for reuse (Western Australian Water Association, 1994). As demonstrated by the release of the Draft Guidelines for the Reuse of Greywater in Western Australia, Western Australian authorities have relaxed restrictions on domestic greywater reuse, and could further demonstrate their commitment to achieving water conservation by considering more innovative wastewater reuse issues.

Another issue that requires further examination is the impact of pharmaceutical products and endocrine disruptors that are present in human urine. Studies on waters receiving effluent have detected chemicals that have the potential to adversely affect the organisms in that ecosystem. Although usually of low concentration in the waters, these chemicals can accumulate over time in the bodies of organisms, especially those higher in the food chain (Matsui *et al*., 2001). The potential for these chemicals to accumulate in soils or plants needs to be examined carefully.

4

GREYWATER, SEPARATION AND REUSE

Domestic Greywater is probably the most recognised wastewater stream, viewed in terms of public awareness, when domestic wastewater reuse is discussed. Greywater reuse will soon be permitted at the domestic level in Western Australia, providing great potential for water conservation. This chapter briefly reviews the Draft Guidelines for the Reuse of Greywater in Western Australia, and discusses the potential for these guidelines to contribute to domestic wastewater management and improve water conservation. A number of recommendations to aid in the successful implementation of domestic greywater reuse are then made.

4.1 CURRENT STATE OF PLAY

Domestic greywater reuse, governed by State and Local Government Health Acts, is currently not permitted in Western Australia. It is acknowledged, however, that in the order of 20% of Perth homes practice some form of water recycling (Lugg, 1994; Stone, 1996). As of the beginning of February 2002, the Western Australian Department of Health relaxed greywater regulations in order to allow for limited reuse. The decision to allow reuse, made in light of the severe water shortage, allowed for manual application to domestic gardens by bucket only, permitted only for the duration of the existing water restriction period (Department of Health, 2002).

In order to avoid public and environmental health issues related to unregulated reuse the Health Department of Western Australia and the Water and Rivers

Commission have developed the Draft Guidelines for the Reuse of Greywater in Western Australia (Dept of Health WA, 2002).

The Draft Guidelines provide introductory information on greywater including characteristics, typical composition and volumes. The Guidelines then set out;

1. Health and Safety Requirements;
2. Design and Performance Requirements;
3. Greywater Treatment System Options;
4. Greywater Irrigation Options;
5. Design Criteria;
6. Maintenance Requirements;
7. Process of System Approval

The Draft Guidelines are prescriptive rather than performance based, however the release of the guidelines does allow for innovation, with the requirement that system design conform to the proposed Guidelines and Australian Standard 1547:2000 "*Onsite Domestic Wastewater Management*".

The current water shortages have prompted the establishment of a State Water Conservation Strategy by the State government and its agencies, with wastewater recycling of various scales addressed. The reuse of greywater on a domestic scale is one of the methods identified that could be employed to help meet the State's future needs (Western Australian State Government, 2002).

Recycling wastewater for landscape irrigation is not a new practice in the State. Treated effluent from lagoons is used on municipal ovals, parks and golf courses in many country towns of WA, with around 80 reused schemes approved across the State (Mathew & Ho, 1993). The fact that wastewater can be reused on this scale, suggests that greywater reuse on a domestic scale could also be implemented successfully.

In Western Australia there is immense community support for reuse of wastewaters (Western Australian Water Authority, 1994). This attitude is also shared elsewhere in Australia, with surveys in Melbourne indicating that people are interested in the reuse of bathroom and laundry greywater (Cristova-Boal *et al.*, 1994). At present, the implementation of domestic greywater reuse in Western Australia looks to be a promising prospect to aid in water conservation.

4.2 THE NEED FOR GREYWATER MANAGEMENT

Of the potable water supplied for domestic use in Perth, between twenty and forty percent is discharged as "greywater" from laundries and bathrooms. This amounts to around 300 litres per household, per day, for transport, treatment and disposal via the sewerage system. This equals around 110 kilolitres annually per household and some 45 gigalitres per year for Perth.

Water shortages in Western Australia have resulted in the introduction of urban irrigation scheme water restrictions during summer, further resulting in a record increase in the number of domestic bores (not currently subject to restrictions) being drilled in the South West of the State. The use of groundwater for garden irrigation aids in the conservation of scheme water supplies, however, at the same time groundwater resources, particularly on the Swan Coastal Plain on which Perth is located, are under considerable pressure from unsustainable use.

Domestic garden irrigation often constitutes a considerable proportion of the total urban scheme water demand. In Perth, landscape irrigation accounts for up to 55% of all scheme water used for domestic purposes (Coughlin and Higgs, 2000). Despite this considerable usage, there appears to be limited research undertaken on the use of alternative water sources for domestic irrigation.

A number of methods of reuse on a domestic scale are available. The method of reuse can depend upon the greywater output volume, but most importantly, upon the regulations and the performance criteria for treatment. Where reuse is carried out via irrigation, the specific method of irrigation is dependant upon the level of treatment of the greywater (Dept of Health, 2002).

The Draft Guidelines identify two levels of treatment of greywater for reuse. Where no treatment occurs, simple bucketing onto gardens is permitted.

1. Primary treatment systems enable reuse of greywater that has been coarse screened in order to remove solid particles such as lint and hair.
2. Secondary treatment systems enable the reuse of greywater that has been treated to a level equivalent to that of secondary wastewater effluent (typically 20mg/L BOD, 30 mg/L SS and 10 Colony Forming Units /100mL).

The Draft Guidelines stipulate that a minimum of secondary treatment must occur for sub-surface irrigation via drip, and disinfection must take place if surface sprays are to be employed. Pathogens can be present in Greywater, the Guidelines therefore recommend that greywater in which nappies are washed or water that has come into contact with ill people is not reused. Unfortunately, only trench "irrigation" is permitted for reuse of primary treated effluent, though the effectiveness of a trench disposal field for plant irrigation is questionable.

4.3 TECHNOLOGIES

Domestic greywater reuse is common practice around the world, and as such a wide range of technologies exist. This section will review technologies suitable for implementation on-site.

4.3.1 GALVINS PRIMARY TREATMENT SYSTEMS

The Galvins greywater recycling units are one of a range of simple systems that enable reuse of domestic greywater for irrigation purposes. A variety of system configurations and sizes are available, sharing common operation features. Figure 9 below shows the simple design of the Galvins models.

The units consist of concrete tanks with two chambers, the first for sedimentation and the second a pumpout chamber. Primary level treatment of laundry and bathroom greywater is achieved by filtration and sedimentation. The systems have sewer diversion capabilities that enable greywater to be routed to the sewer during the wet months, as well as provide a precaution against system overloading and overflows. The Draft Greywater Guidelines (Department of Health, 2002) require sewer diversion capability in areas where reticulated sewer systems exist.

The level of treatment restricts reuse to simple irrigation trenches, consisting of a sub-surface distribution pipe underlaid with aggregate to disperse effluent (see Figure 10**).** Although this irrigation method may not be extremely effective, it is a simple, low maintenance system that is also relatively cheap in comparison to higher-level treatment and irrigation systems. The systems require electricity to run the irrigation pump and do require regular maintenance and sludge pumpout. Further information is included in the Appendices

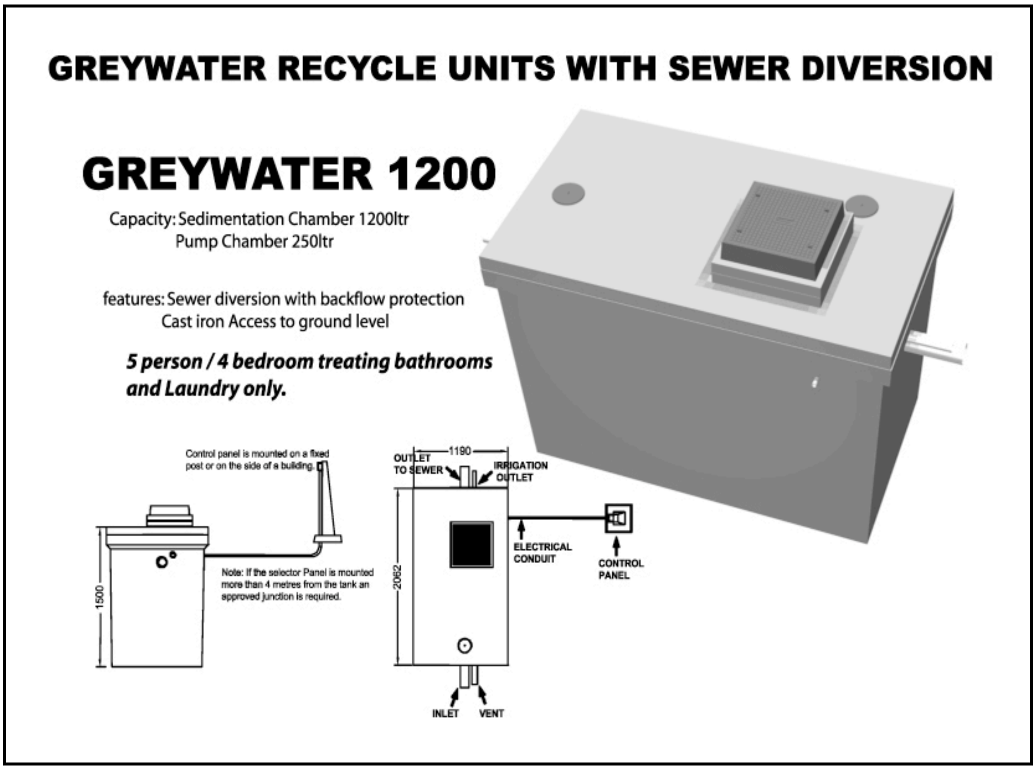

Figure 9 Galvins Greywater treatment unit.

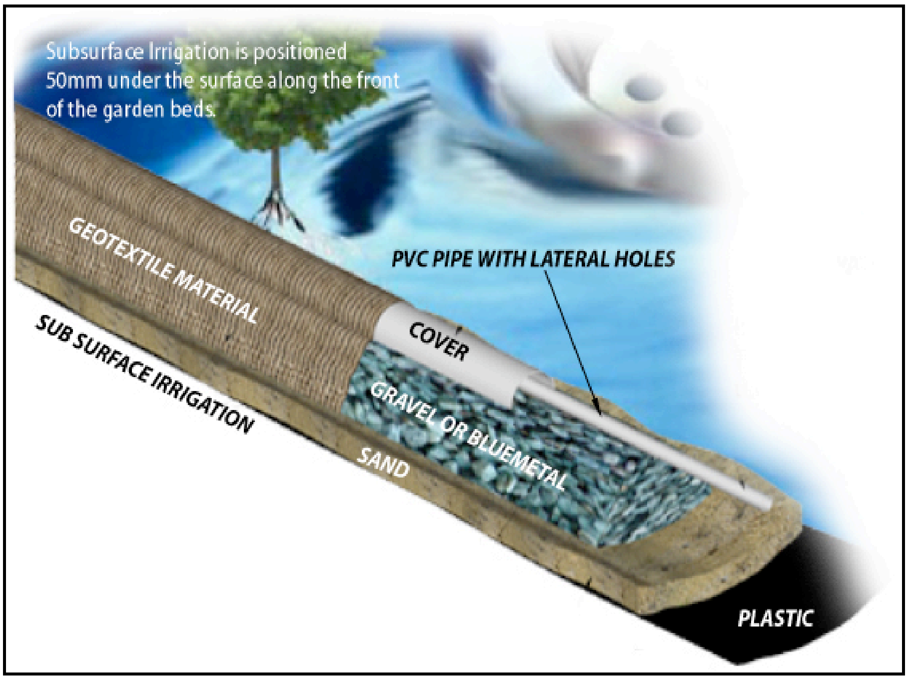

Figure 10 Trench Irrigation method for Domestic Greywater reuse.

4.3.2 CONSTRUCTED WETLAND SYSTEMS

Constructed Wetlands are either of Free Surface flow or Subsurface Flow types. In these systems, wetlands are employed to remove nutrients and pathogens, much like the processes that occur in natural water bodies. The wetlands contain a suitable media, such as gravel and limestone, and are planted with vegetation that has high nutrient uptake ability. As water passes through the wetlands, solids are detained by the media and roots and decompose in both aerobic and anaerobic conditions (similar to septic tanks). Pathogens die-off due to a combination of the retention time in adverse conditions and ultra-violet radiation, nutrients are taken up by plants to provide energy for growth. After water has passed through the system, it can be reused via irrigation or disposed of via other methods (e.g. evaporation). Figure 11 is a schematic of a typical subsurface flow wetland, showing the path of wastewater through the media to a final collection unit.

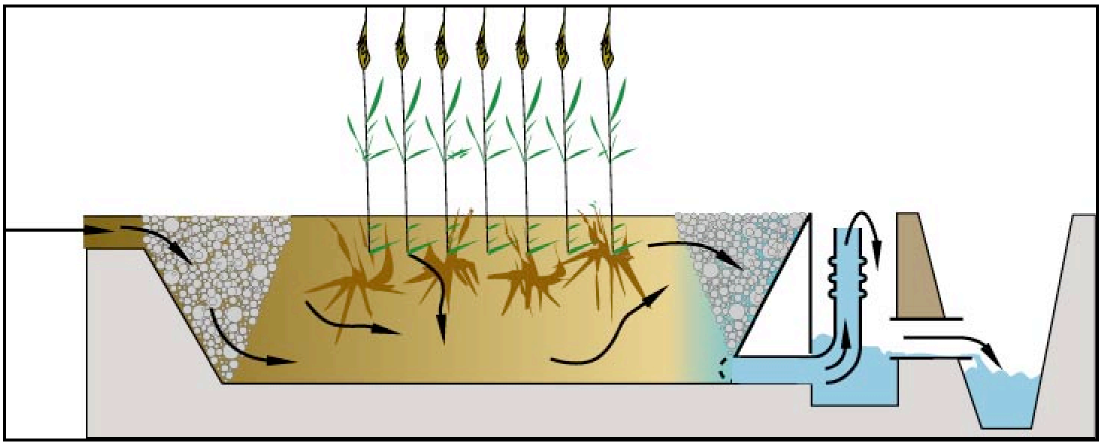

Figure 11 A typical Sub-surface Flow Constructed wetland

4.4 OPPORTUNITIES AND LIMITATIONS

The greatest impact of greywater reuse is the water savings generated. Table 5 below list figures of potential savings for Perth at differing levels of domestic implementation and reuse. Although reuse volumes at the bottom end of the scale are low, the reuse effectively increases the water resources available in the State. Although the public may support reuse, system installation is likely to be limited by the financial implications for the householders. Initial capital outlay for installation of systems is likely to be the greatest barrier to implementing domestic greywater reuse, therefore householders need to be informed of the wide range of benefits including water savings and the subsequent reduction in household water service expenses.

Table 5 Potential Water Savings Obtained

Proportion of Perth households undertaking Greywater reuse (%)	***75% of greywater reused (GL)***	***100% of Greywater reused (GL)***
5	*1.7*	*2.3*
10	*3.4*	*4.5*
20	*6.8*	*9.0*
50	*16.9*	*22.5*

The Draft Greywater Guidelines provide information on how to correctly calculate greywater output volumes, which determines system sizing and subsequent sizing of the irrigation area. A possible shortcoming of greywater reuse systems is their ability to provide sufficient water to irrigate a domestic garden (or part of). If effluent output is insufficient, due to low household use, a supplementary water source may be required. A balance must therefore be found between the expense of installing a dual system and the likely benefits. Conversely, in instances where land availability or irrigation opportunities are limited, greywater volumes may be too great, requiring diversion to sewers or alternative systems, another financial burden for the householder.

Diversion of excess greywater to the sewer may also be required during the wet months of the year when plant water needs are provided by rainfall and when recharge of groundwater occurs. Problems that may eventuate include ‘drowning’ of plants and waterlogging of soils, ponding of water (presenting health risks via human contact) and contamination of groundwater. One method of avoiding these problems is through the use of a soil moisture sensor that regulates irrigation scheduling.

Great potential exists for greywater reuse in arid regions. Contrary to the circumstances in urban areas, the cost of implementing greywater reuse schemes can be competitive with the cost of other water supply options especially when low yield or unsustainable sources are used.

It can be seen that there exists a need for further research into integrating greywater treatment and irrigation systems. Systems are required that are capable of effective irrigation, while also protecting human and environmental health. Implementation of systems that are not able to fully satisfy those requirements create the risk that another water source could be wasted and confidence in the reuse of wastewater reduced.

4.5 THE WAY FORWARD

Due to the large expense involved in implementing domestic greywater reuse in existing homes (especially due to plumbing changes), the future of reuse lies in encouraging the installation of systems in new housing. The provision of financial incentives by the State Government, to encourage use of sustainable water systems, would aid in reducing the financial burden on householders. Indeed, one recommendation within the State Water Conservation Strategy (2002) is the use of a rebate scheme for efficiency projects that reduce demand on scheme water, such as wastewater reuse systems.

Employing command and control devices as a disincentive to those that continue to irrigate in an unsustainable manner, provide an option to help regulate water use. Similar to the water restrictions previously employed within the State, regulations on urban irrigation schedules could be implemented. An example of this can be found in the State Water Conservation Strategy (2002) with the development of 'minimum performance standards' for water use fixtures such as irrigation system, and penalties for irrigating during specific periods, for example, during winter and drought periods.

Most importantly, the need exists to promote domestic reuse through increasing public awareness through education programs, promotional opportunities exist in the creation of 'display homes' that employ reuse and allow public viewing. A shift in attitude needs to occur, specifically towards water use practices and the manner in which wastewater is perceived. Education further needs to address safety considerations and health requirements to ensure that reuse is carried out in a controlled environment.

Of the reuse initiatives proposed in this dissertation, domestic greywater reuse is the closest to being implemented. It is hoped that the relaxing of regulations in the domestic wastewater reuse field has set a precedent and will make it easier in the future to implement other safe, sustainable reuse technologies and programs.

5

BLACKWATER, SEPARATION AND REUSE

Of the individual fractions of the domestic wastewater stream, blackwater is commonly perceived as having the highest risk in reuse. This chapter demonstrates that through taking the necessary precautions and careful management, blackwater can successfully be treated and reused in a domestic setting. Firstly the general characteristics of blackwater are discussed, the technologies available for sustainable treatment will then be examined and finally, the potential for reuse will be looked at.

As previously discussed, the blackwater fraction generally consists of faeces and urine, which can be separated to form the 'Brownwater' and 'Yellow water' streams. However, instead of considering the faecal component as brownwater, as suggested by the revised wastewater palette, it will continue to be called blackwater, as this then takes into account kitchen wastewater. Kitchen wastewater is strictly greywater, however, it is best removed from the greywater stream and integrated into blackwater. The most important reason for separating the faecal fraction from other wastewaters is to remove the organic portion, therefore kitchen wastewater, because of the high level of contaminants (grease, food wastes) is best treated with the faecal wastes.

5.1 CHARACTERISTICS

The characteristics of blackwater were briefly examined previously in order to provide a comparison to the other streams. These characteristics need to be further looked at to help in the understanding of treatment requirements and the reuse potentials as blackwater presents the greatest risk to public health.

5.1.1 VOLUME

Blackwater volume is mostly dependent upon the toilet type. Conventional toilets consume prohibitive amounts of water, resulting in high dilution of the blackwater. Low volume-flush type toilets are much more efficient at keeping the blackwater in high concentrations and non-flush toilets enable collection of un-diluted blackwater.

With urine removed from the blackwater stream, the volume is reduced significantly. The mass of faeces produced per person in a year is between 30 and 45 kg (wet weight), or around 10-15 kg of dry matter (Lentner *et al.*, 1981, cited in Vinneras *et al.*, 2001). If kitchen water is added to the stream, as previously recommended, the volume will increase by a substantial amount.

5.1.1.1 NUTRIENTS

The nutrient levels in blackwater are greatly reduced once urine is removed, with only Phosphorus remaining in relatively high concentrations. Depending on the treatment method, nutrients can be retained and are reused via composting to improve soil. Other treatment systems digest the solids and produce liquid effluent for reuse, often removing much of the nutrients, although some remain in the effluent, which is suitable for irrigation.

5.1.2 BIOCHEMICAL OXYGEN DEMAND

The Biochemical Oxygen Demand (BOD) is a method of measuring the quantity of oxygen required during the process of decomposition of organic matter in wastewater (or other waters) by aerobic biochemical activity (Ho, 2000a). The conventional method of disposing of wastewaters to water bodies in the environment increases the BOD of those waters, therefore reducing the Dissolved Oxygen (DO) content of the waters. Low DO in water ecosystems can result in toxic discharges from anaerobic bacteria (identifiable by bad odours), while aerobic organisms, including the bacteria involved in the natural process of organic decomposition and vertebrates (e.g. fish) cannot survive (UNEP-IETC, 2002).

5.1.3 PATHOGENS

The Blackwater fraction is the stream with the highest pathogen concentrations. Urine and greywater are generally pathogen free, unless contamination from faeces has occurred (Matsui *et al.*, 2001). For ease of treatment, and to enable safe reuse, it is essential to keep faecal wastes separate from the other streams. Although chemical disinfection enables safe reuse, more sustainable practices, employing natural processes can be used to treat waste for reuse.

5.2 TECHNOLOGIES

A wide range of on-site blackwater treatment technologies exist worldwide, ranging from very low technology types, suitable for implementation in remote regions, to expensive high technology systems. Many systems exist in various forms, with the basics of operation being essentially the same as others worldwide. The benefit of having so many options is that systems can be tailored to individual site requirements. This section will briefly examine some of the popular system types, suitable for implementing in Western Australia, with a focus on those systems produced in Australia.

5.2.1 AEROBIC TREATMENT UNIT

Aerobic Treatment Units (ATU) are suitable for treating all fractions of domestic wastewater. However, they can be employed to treat wastewater received only from toilets and kitchens, and then provide a source of irrigation water. The BioMAX system will be described here (www.biomax.com.au).

The BioMAX is an ATU developed and marketed in Western Australia. Various scales of the system are available, including domestic systems through to large commercial and municipal buildings. The Units consist of a four-stage treatment process, which occur in individual chambers, figure 12 shows the interior of the system. The processes that occur in each chamber are described below;

(1) Anaerobic Digestion Chamber: Solids within the wastewater settle out in the chamber, where bacteria, in the absence of oxygen, reduce the suspended solids in the wastewater. Wastewater minus most solid matter moves on to the second chamber.

(2) Aerobic Digestion (Aeration) Chamber: This chamber receives the partially treated wastewater and aerates it via a compressor and air diffusers. The chamber contains submerged media that acts as a biological filter on which both anaerobic and aerobic bacteria can utilise organics.

(3) Clarification Chamber: After aeration, any remaining solids are allowed to settle out in the clarification chamber, which then pumps the sludge back to the anaerobic (first) chamber. Wastewater is then passed to the next chamber, via an outlet set below the effluent surface level to prevent floating solids passing through. Sludge returned to the first chamber enables further digestion of solids and provides a food source for bacteria, when inflow is low or nil.

(4) Disinfection Chamber: The effluent undergoes chlorination in the final chamber. Faecal coliform levels are reduced to levels that enable the water to be reused via irrigation, either below, or above ground. The last chamber is a simple pumpout chamber.

At the end of treatment the effluent quality is well within the requirements of to enable reuse via irrigation systems:

- BOD, < 20mg/L
- SS, < 30mg/L
- Free Chlorine, not less than 0.5mg/L (at maximum flow)
- Faecal Coliform, < 10 faecal coliform organisms per 100mL

As these systems are highly effective it is likely that all the domestic wastewater streams would be directed to them, instead of separating the streams and having a number of treatment systems. Where only blackwater and kitchen wastewater are directed to the systems, they can be seen to be under-utilised, and due to the relatively low wastewater inflow volumes, would be limited in their effectiveness as a supply for garden irrigation

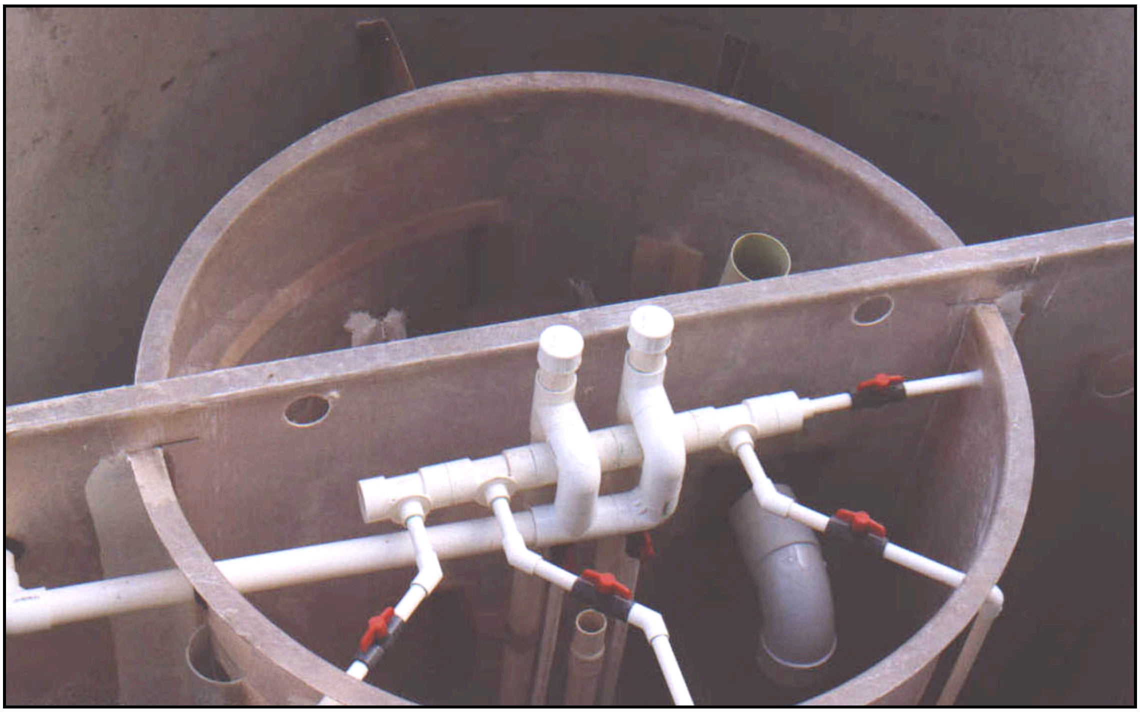

Figure 12 Interior of Biomax System

Further barriers to the use of these systems are the initial installation costs (domestic scale: ~$10,000-15,000) and the ongoing power and maintenance costs. These systems are high technology systems that require professional maintenance, and therefore can be expensive to maintain, like septic tanks they also require desludging. To ensure proper maintenance procedure is followed the WA Health Department requires regular maintenance inspections of the systems by the installation company.

5.2.2 COMPOSTING TOILET

Composting toilets, in contrast to ATU are low technology options suitable for on-site processing and reuse of blackwater. Unlike ATU a solid resource (compost) is created for reuse, instead of a liquid. As with other systems, a diverse range of composting and vermi-composting toilets exists. Two generic systems, produced by Dowmus, will be described below.

5.2.2.1 DRY COMPOSTING TOILETS

Dry Composting Toilets are a simple technology, not unlike traditional disposal methods, that enable composting of faeces and organic wastes for reuse as a soil conditioner/ plant fertiliser. The major benefit of this toilet is the water savings generated by the lack of use of a flushing mechanism. Systems generally employ a sealed unit for collection of wastes under a porcelain toilet pedestal that allows faeces and urine to drop through to the chamber.

A dry composting toilet operates under aerobic conditions, with bacteria digesting organic wastes (kitchen and garden wastes can also be added to the system), producing highly reduced organic humus. A schematic of the system is in Figure 13. The process can be supplemented by using earthworms to aid in decomposition of the wastes, the process then being vermi-composting. To enable compost to mature, dual chambers are best used alternately to allow each to rest prior to compost removal, or design to size such that the compost remains in the chamber for at least 6 months (Mathew *et al*., 2000; UNEP-IETC, 2002).

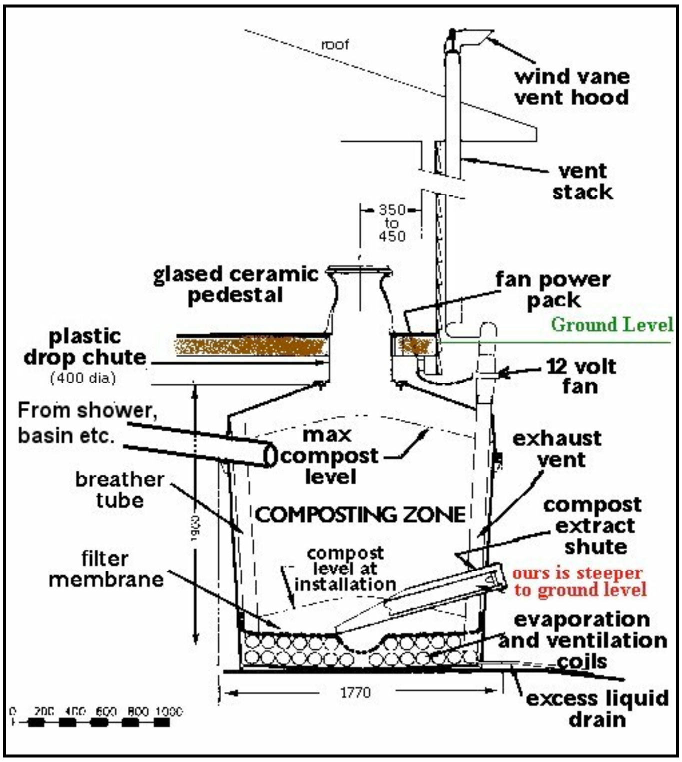

Figure 13 Dowmus Dry Composting Toilet

The main difficulty with implementing this technology is that the Australian public has become accustomed to the conventional flushing toilet. Unfortunately the "out of sight, out of mind" attitude, would make it difficult to employ technologies that require interaction with wastes. Advances in construction of these systems mean that odour is controlled by extraction systems (which also aid maintaining aerobic conditions) and compost can safely be removed via a hand auger that requires minimal contact with the compost product.

5.2.2.2 WET COMPOSTING TOILET

The Wet composting toilet may be more favourable to implement in Australia as the conventional flushing toilet is employed, instead of a pit style drop toilet.

These systems enable the solids to decompose, as with a dry composting toilet, and produce rich, fertile compost. These systems can also receive the other wastewater fractions. The solids are held above the bottom of the compost chamber by a screen, allowing effluent to drain through to the bottom. When effluent levels near the solid wastes, a pump switch activates and the effluent is removed for treatment (e.g. by constructed wetlands). (Mathew *et al.*, 2000; UNEP, 2002)

If the system receives only kitchen and flush wastewater, removal of excess effluent may not be required, though this needs further investigations. Options include evaporating the excess effluent off or sizing the chamber for longer storage periods and supplementing the organic waste with household and garden organics.

In order to implement urine separation the toilet could be a separation pedestal, the Aquatron system, discussed previously is an example of a system that enables integration of urine separation and composting processes. It can be questioned whether urine separation is required when the nutrients will be held within the compost and reused on-site. The value of urine for other nutrient reuse areas, such as agriculture must therefore be taken into account when deciding on the preferred process.

5.3 REUSE POTENTIAL

As with the other wastewater fractions, the form of reuse differs with the type and level of treatment. The systems outlined above identified two different resources obtained from treating blackwater.

Composting of faecal wastes to provide a nutrient rich source of garden fertiliser has great potential for implementation in the State. Unfortunately, the expense of treating blackwater on-site to a level sufficient to enable garden irrigation is likely to be prohibitive to many householders. The reuse of wastewater via treatment and irrigation can be cost effective for those that do not have access to reticulated sewage.

6

RECOMMENDATIONS FOR INTEGRATED DOMESTIC WASTEWATER MANAGEMENT

This chapter makes recommendations for the content of an integrated plan to treat and reuse domestic wastewater streams, employing appropriate technologies.

Recommended actions need to be sustainable, not only from an environmental perspective but also from a financial and social viewpoint.

Actions that can aid in the achievement of a number of objectives are recommended where possible. It is encouraging to see that many recommendations are paralleled in the Recommendations of the Western Australian Water Reuse Forum, the State Water Conservation Strategy and the recent Water Symposium.

6.1 OBJECTIVES

The main objective is to:
Implement integrated domestic wastewater management and reuse in Western Australia.

Within this objective, this objectives also exists, to:
Adopt and encourage Domestic Greywater, Blackwater and Yellow water reuse in Western Australia.

6.2 ACTIONS

The actions to achieve the above objectives have been classed within three broad time frames. Firstly, the initial Research period, a Developmental stage and lastly, Implementation.

6.2.1 RESEARCH PERIOD

6.2.1.1 RESEARCH AREAS

- Determine the feasibility of implementing these processes and technologies in Western Australia.

The focus here should be on social surveys, determining attitudes and perceptions of domestic wastewater reuse, whilst also providing information. This information aids in determining what processes, if any, are viewed as acceptable by the public and also helps later in the implementation process as it can identify areas in which to focus education.

- Review all information available of previous domestic water reuse trials and projects in Western Australia, and where relevant, Australia or world-wide.

The regulatory authorities would benefit from bringing together all the information from the various agencies and establishing a library of wastewater research. This resource would aid in development of system guidelines and performance requirements.

Unfortunately, due to the little experience with the urine separation process, a significant review of foreign information would be needed.

- Determine appropriate technologies for implementation in Western Australia.

In order to aid in determining what an 'appropriate' technology is, the *Criteria for Selection of Wastewater Management Technology*, as determined by Ho (2000b) is recommended. The criteria require the technologies to:

1) Protect Public and Environmental Health
2) Be Economically Affordable
3) Be Socially/ Culturally appropriate

6.2.1.2 TECHNICAL INVESTIGATIONS

- Testing of technologies

Trials of a wide range of processes should be carried out under controlled conditions. This is essential to determine the effectiveness of the systems in protecting environmental and public health. An example of a site carrying out such a testing process is the United Nations Environmental Programs International Environmental Technology Centre (UNEP-IETC) at Murdoch University. The Centre has a range of sustainable wastewater reuse technologies operating and being monitored. Technologies including composting toilets, simple greywater reuse and ATU irrigation systems demonstrate that safe reuse can be implemented in a domestic environment.

Dillon (2002) emphasizes the importance of ensuring that wastewater reuse schemes are carefully implemented, ensuring effective protection of public and environmental health. Research can identify areas of concern and help to address them. Failures, especially with regard to public health could significantly reduce the public's confidence in reuse, threatening the ability to implement reuse programs successfully.

A wide variety of wastewater reuse configurations could be tested, including individual fractions and integrated reuse processes.

- Determining reuse effectiveness/potential

The potential for reuse of the different fractions varies considerably. Greywater reuse is effective for garden irrigation, however it may not be effective as a source of nutrients, such as urine would be. Research into the different reuse abilities and effectiveness therefore needs to be carried out. The most important testing here would involve the agricultural potential of urine.

6.2.2 DEVELOPMENTAL PERIOD

• Develop technology demonstration sites.

Demonstration sites for the public, helping in the community education process, as well as enabling ongoing collection of data could be set up around the State. Demonstrating various integrated technologies in operation will aid people in deciding which technologies are suitable for their needs, while also demonstrating how successful these processes can be. Sites could be single houses, but preferably on the scale of a housing development area, or an 'urban village' which better showcases the potential for integrated wastewater reuse, including other conservation features such as stormwater collection and efficient irrigation.

• Establish guidelines for domestic systems and reuse of Blackwater and urine.

Greywater guidelines have already been released, reuse guidelines for the other fractions could be developed. Reuse of urine in agriculture and other areas would require a wide range of regulatory changes.

6.2.3 IMPLEMENTATION PERIOD

• Promote domestic reuse in the Public arena

Education program, similar to that employed with efficient water use initiative, should be developed. Important areas of education include system operation, health requirements and environmental protection issues.

The State Government has recognised the importance of community support, stating in the findings of the Western Australian Water Reuse Forum that:

> *"actual (as opposed to perceived) health issues associated with the use of reclaimed water represent a manageable issue. Whilst it requires attention it should not constrain development of recommended approaches."*
>
> *"there is a need to actively engage the community on the use of reclaimed water, in order to define critical constraints, and to provide "comfort" regarding the concept over a number of years prior to implementation of more sensitive schemes." In this case the introduction of the urine separation process and*

> *composting toilets can be seen as the 'sensitive schemes' (Western Australian Water Reuse Forum, 2002).*

The promotion can also be extended to the corporate environment. Groups could be encouraged to act as good corporate citizens by implementing sustainable wastewater technologies.

- Encourage Innovation within the relevant Industries

Focus industries include wastewater treatment technologies, irrigation and agriculture/horticulture. Incentives and technical aid (information and technology sharing) can help innovation. Innovation can also be encouraged by the development of regulations that enable system design to be flexible, that is, guidelines that are performance based instead of strictly prescriptive. The requirement that systems achieve certain performance standards allows for flexibility in design, instead of strict

- Implement a Rebate Program

To reduce the cost pressures on householders a rebate program covering a proportion of the cost should to be implemented. The State government currently employs this to promote the use of domestic solar water heating systems.

- Government Implementation

The State Government could lead by example by implementing wastewater reuse scheme in Government buildings and grounds. Although not a domestic setting, conditions are often similar and could demonstrate the governments commitment to environmental protection.

7

MANAGEMENT, REGULATION AND POLICY

7.1 CURRENT INITIATIVES

7.1.1 THE WESTERN AUSTRALIAN WATER RECYCLING FORUM

The forum was established by the CSIRO and consisted of a board of representatives from State regulatory authorities and academics with knowledge in the water recycling field. It is important to note that all forms of wastewater were considered, not only the domestic streams. The forum was conducted in March 2002 and presented the findings of the research group. The group identified options for wastewater reuse, those being:

- Industry;
- Horticulture / Agriculture;
- Municipal playing fields, parks and golf courses;
- Woodlots;
- Domestic gardens;
- Commercial premises;
- Domestic in-house use

(Western Australian Water Recycling Forum, 2002).

Of most interest to this dissertation are the domestic and horticulture/agriculture options. Unfortunately because domestic reuse volumes were seen to be negligible, in comparison to the large-scale reuse initiatives, domestic reuse was at the lower end of the scale of importance for the Forum. For example domestic greywater reuse was estimated to be in the order of <2 GL/year, where as between 8-20 GL/year could be reused by the Horticultural industry (Western Australian Water Recycling Forum, 2002). The view that domestic wastewater reuse volumes are insignificant may be due to the predominant line of thought that conventional large-scale engineering approaches are needed. Stuart Henry of the Western Australian Master Plumbers Association believes that with substantial promotion and education, uptake of small-scale greywater reuse technologies could provide reuse volumes of a much greater magnitude (Personal communication).

The Forum demonstrated that although the current State Government and the Authorities are committed to investigating sustainable alternatives to aid in water conservation, the preference is to take a conventional approach and implement large-scale engineering 'solutions'.

Other important findings of the Forum, which apply to small-scale domestic reuse, as well as the larger initiatives, are the issues that limit the use of reclaimed water in the Perth Metropolitan Area. These are:

- potential environmental impacts on the Swan Coastal Plain (especially nutrient impacts)
- equity in pricing - the high price of reclaimed water in comparison to use of scheme and groundwater
- maintenance of public health
- community attitudes and perceptions regarding reclaimed water usage

7.1.2 STATE WATER CONSERVATION STRATEGY, JULY 2002 (DRAFT)

The Draft State Water Conservation Strategy was released to recommend a number of actions to aid in management of the States most precious resource. A number of recommendations are related to effluent reuse, although not specifically addressing on-site domestic reuse, can help to 'pave the way' for implementing on-site technologies. The relevant recommendations are:

Recommendation 23

"Facilitate the development of a transparent and comprehensive process for evaluating the costs and benefits of all known reuse options and alternative supply options. Assess their maximum potential contribution to reducing demand on scheme supplies or other constrained water supplies."

This recommendation would be valuable in demonstrating that wastewater reuse technologies and processes can be very beneficial in terms of water conservation but also economically and socially advantageous. Investigating costs and benefits would also aid in identifying barriers and problems with regards to implementation of reuse schemes. The fact that "all known reuse options" are recommended to be investigated suggests that a wide range of technologies will be included, such as the urine separation/reuse process, and not only those technologies traditionally viewed as 'alternative'.

It is hoped that the investigating authorities will not overly focus on the large-scale options, but also give due consideration to the domestic options. Due to the potential for large-scale engineering options to reuse very large volumes of wastewater in comparison to small-scale systems, the on-site options may be perceived as less important and therefore may suffer from lack of attention.

Recommendation 24

"Implement a rebate or 'bounty' system for allocating funds to wastewater reuse or alternative supply systems or efficiency projects that reduce the demand on scheme water, based on a $/ML installed capacity which reflects avoided costs."

The rebate system recommended above is most likely made with large-scale systems, such as industrial scale, in mind. A rebate system could also be implemented for domestic reuse initiatives. The State Government currently has similar programs in place; for example, a $1000 rebate is available for households that fit solar water heater systems. An incentive based program would likely have more success than a State requirement for wastewater reuse at the domestic level. Regulations on new housing require that low flush toilets and water fixtures are used, however, domestic wastewater reuse, due to the level of householder involvement and dedication, would suffer from use of such regulations.

Recommendation 25

“That the government review the outcomes of the Western Australian Water Reclamation Forum and address issues and opportunities in the White Paper developed from the Forum.”

As discussed previously, the WAWR Forum reviewed all levels of water reuse, with domestic reuse being of a lower priority than other options. As domestic reuse is vastly different than other options, it may benefit from being considered individually.

7.1.3 WATER SYMPOSIUM

The Western Australian Government recently held 19 public forums statewide to enable the government to present the State Water Conservation Strategy and provide the opportunity for the Public to present their thoughts on water issues in the State.

The outcome of the forums was the Symposium held on the 7th-9th of October at Parliament house. At the symposium information from the proceeding forums and new issues were discussed to enable a range of recommendations to be outlined. The Symposium once again demonstrated that the public immensely supports the reuse of wastewater, as identified in the recommendations. The wastewater related recommendations are given below;

Recommendation 8

"Undertake additional research into greywater reuse within the urban environment."

Recommendation 11

"A target greater than 20% by 2012 be set for wastewater reuse."

Recommendation 15

"Investigate the option of aquifer recharge and reuse of treated wastewater."

Recommendation 16

"A research fund be established to fund research in a number of areas, including aquifer recharge and wastewater reuse technologies…" (Western Australian State Government, 2002b)

7.2 REGULATION

7.2.1 HEALTH ACT 1911; HEALTH (TREATMENT OF SEWAGE AND DISPOSAL OF EFFLUENT AND LIQUID WASTE) REGULATIONS 1974

The prime regulatory paper for Western Australian wastewater management, this sets out the method of making an application for installing a wastewater system and having it approved.

Installations of new, or upgrades of old, systems require an *Application to Construct or Install an Apparatus for the Treatment of Sewage* to be made to the Executive Director, Public Health or local government. Applications must include full details of the proposed system and include payment of the required application, inspection and report fees. Construction shall not commence until an approval for the system to be constructed has been issued.

Once the system has been constructed, it cannot be used until an inspection by the local government Environmental Health Officer has occurred and approval for use obtained.

7.2.2 AUSTRALIAN/NEW ZEALAND STANDARD 1547:2000, ON-SITE DOMESTIC-WASTEWATER MANAGEMENT

The Standards governs the technical implementation factors.

Specifics include:

- *Performance: This sets out the performance objectives, requirements and criteria.*
- *Management: To ensure sustainable management of on-site systems, this section sets out management procedures, criteria and implementation guidance.*

- *Compliance: This sets out the means to achieve compliance with the Standard, including site evaluation and treatment unit information.*

7.2.3 DRAFT GUIDELINES FOR THE REUSE OF DOMESTIC GREYWATER IN WESTERN AUSTRALIA

As discussed in Chapter 4, these guidelines set out the States requirements for on-site disposal of greywater. Design specifications are as the AS 1547:2000, therefore, compliance with the Guidelines ensure compliance with the Standards. Submitting an application for system approval is carried out as per the Health Act 1911.

7.3 POLICY

The State government and its Authorities need to establish a policy statement with regards to water reuse to demonstrate their commitment to achieving water conservation.

For example, a statement similar to that of the greywater policy could be stated thus:

"Domestic Wastewater recycling will be supported so as to conserve water and utilised in a manner so as to not to cause nuisance, taking into account the interests of public health, surface/ground water environmental impacts and its effect on the operation of sewerage systems"

A policy statement can aid in establishing legislation by enabling the Government to focus on the desired objectives and legislate to permit reuse.

8

CONSTRAINTS OF DOMESTIC WASTEWATER REUSE

This chapter examines the range of issues that can constrain domestic wastewater reuse. This includes human (social), environmental and economical issues.

8.1 SOCIAL FACTORS

8.1.1 CULTURAL PREFERENCE

Many of the technologies and processes discussed in this dissertation would be unfamiliar to many people in urban Australia. Implementing technologies that are unfamiliar, or where public perceptions may be unfavourable, can be challenging. Public perceptions and attitudes can be difficult to alter, especially when issues such as public health are involved.

As the success of implementing sustainable wastewater technologies depends on public commitment, it is essential to ensure people are educated on the benefits and have the knowledge to make a fair assessment of the technologies.

Factors identified that aid in encouraging acceptance include appealing design, ease of use, operation and maintenance, cost competitive with conventional technologies and high performance/efficiency (Roediger, undated; Matsui *et al.*, 2001).

8.1.2 PUBLIC HEALTH RISKS

The foremost issue with regards to wastewater treatment and reuse is protection of public health. Any reuse system, technology or program should protect the health of the public.

8.1.2.1 PATHOGENS

The foremost issue with regards to domestic wastewater reuse and public health is the potential for people to contract diseases through contact with or consumption of wastewater. The human health risk can be eliminated by tertiary treatment of wastewater, which involves disinfection with chemicals (chlorination) or Ultra-violet radiation. Unfortunately tertiary treatment can be expensive, and often unnecessary if proper precautions are taken.

Pathogens are generally present only in high amounts in blackwater; therefore it is this fraction that is perceived as the having the greatest risks when reused. Greywater often contains low amounts of pathogens, however precautions, such as sub-surface disposal can reduce the risks to public health. Composted biosolids often contain pathogens of various types; therefore precautions are required to prevent human infection. Sufficiently long storage periods can induce pathogen die-off, and below ground surface application can prevent contact (Gibbs *et al.*, 1997).

Urine is typically sterile, but often has been contaminated to some degree, a sufficient storage time to allow pathogen die-off is therefore recommended.

8.1.2.2 ENDOCRINE DISRUPTORS

Endocrine glands are responsible for producing and releasing hormones, the ‘chemical messengers’ that help maintain proper functioning of the human body, including growth and sexual development. The endocrine system is the combination of these glands, including the pituitary gland and the sex organs and the receptors that receive these ’messages’. Endocrine disrupting chemicals (EDC) are typically chemical ‘mimics’ of hormones, and can be either manufactured, such as hormone replacements, or occur in nature. EDC have the potential to bind with the body’s receptors and act as a mimic, that is, imitate the natural chemicals and induce an unnatural response in the body (Colborn *et al.*, 1996).

A number of studies have been undertaken on the effect of EDC, introduced into the ecosystem. Research has been undertaken on EDC introduced into aquatic environments through wastewater effluent. Results found that fish populations in receiving water bodies with high levels of synthetic oestrogen (typically from oral birth control, but also from the breakdown of personal care products) suffered from reproductive abnormalities (Colborn *et al.*, 1996; Snyder, 2002). Another example of harmful chemicals are Cytotoxic drugs, chemicals used to treat cancer patients (by destroying cells), which may be present in urine (NH&MRC, 1988).

Concerns about the possibility of human exposure to EDC, most likely through drinking water have been raised. The US has therefore introduced requirements for screening for the presence of EDC when potential to contaminate drinking water or food (Snyder, 2002).

Conventional wastewater treatment methods, such as the Activated Sludge Process, remove a degree of the EDC, however, advanced technologies, such as membrane filtration and absorption techniques, can be employed for improved efficiency of EDC removal, unfortunately at great cost (Davis et al., 1999, Schafer and Waite, 2002). The need to remove EDC depends on the type of reuse. Use of such technologies would produce extremely high quality water, suitable for human consumption and too expensive to use elsewhere.

An option to the use of expensive, high technologies is the urine separation process, which can aid in reducing the levels of EDC reaching the environment through the wastewater stream. As consumed EDC are excreted in urine, separation of urine removes them from the general wastewater stream, assuming that the remainder of the stream is treated and disposed of in the conventional manner. The concern with the use of this process is the lack of knowledge on the effect of EDC in the urine once it is reused. The most common form of reuse of urine has been as a plant fertiliser. Unfortunately, due to this lack of knowledge, the reuse of urine on food crops for human consumption has been banned in the European Union, limiting the reuse potential. Further research is required to determine the potential for plant uptake of EDC and the effect of EDC when retained in soils.

8.2 ENVIRONMENTAL HEALTH RISKS

Protection of environmental health is also a priority, as domestic wastewater does not contain chemicals or heavy metals in high concentration, the greatest concern is nutrient contamination.

8.2.1 NUTRIENTS

The reuse of wastewaters with high nutrient concentrations needs to be carefully managed. Leaching of nutrients, potentially resulting in contamination of ground and surface waters is of particularly concern on the Swan Coastal Plain. If we look at each fraction we can identify a range of issues that need to be addressed.

8.2.1.1 YELLOW WATER

As previously discussed, reuse in an urban setting may not be suitable on the Swan Coastal Plain. The high concentration of nutrients found in urine pose a great threat to ground and surface water in areas where the soil is sandy. Some native plants have also developed low tolerances levels for nutrients.

Where urine reuse occurs for agriculture, precautions must again take place to ensure the environment is able to safely receive high nutrient levels. Use of chemical fertilisers has demonstrated the potential for eutrophication of waterways, therefore urine must be used carefully in environmentally sensitive regions.

8.2.1.2 GREYWATER

Greywater has relatively low nutrient concentrations, depending on the type of cleaning products used in the household. Low phosphorus products are better employed to reduce leaching risks, but otherwise with careful management, the nutrient levels are low enough to provide a source for plants and not 'over-load' the surrounding environment.

8.2.1.3 BLACKWATER

Chapter 5 discussed the difference between nutrient concentrations in blackwater with and without urine separation. Effluent from ATU reused via irrigation can still have high nutrient levels and can result in problems as discussed above. Compost is high in nutrients, but is safer to reuse, as nutrients are not held in water, the usual conveying medium (Mathew *et al.*, 2000). A concern with compost is the concentration of heavy metals

8.3 ECONOMIC ISSUES

On-site wastewater reuse can be a cost effective method of disposing of a household's wastewater. Reuse of wastewater can often generate water savings that ensure an acceptable payback period. Unfortunately, the householder typically covers small-scale systems costs. In some cases, systems can be quite expensive, depending on the type selected, or the type required. Sometimes householders are restricted in their system selection due to surrounding environmental conditions, whether there is access to sewers and the site location.

System costs range from the expensive ATU through to very cheap greywater reuse systems. As scheme and ground water is very cheap, the financial savings obtained from replacing scheme/bore irrigation with wastewater are minimal, with long payback periods. As the State Water Conservation Strategy (2002) recommends improving the pricing structure of scheme water (more realistic pricing), we can expect water costs to increase in the near future. This will improve the payback periods for wastewater reuse systems, and make them more appealing to the public.

9

CONCLUSIONS

The current centralised approach to wastewater disposal is not a sustainable process. This is an energy intensive process that ignores the fact that water is a finite resource and views wastewater as a problem, rather than an important resource. The reuse of wastewater is becoming increasingly popular; however alternatives to the current reuse strategies exist. Each component of the domestic wastewater stream can be sustainably treated and reused in a domestic setting

An emerging paradigm in wastewater reuse, urine separation is now being successfully employed in many European countries. The separation process enables the urine, which contains high concentrations of plant available nutrients, to be reused as fertilizer. Blackwater and Greywater reuse, which are already popularly employed in Western Australia can further aid in water management.

The urine separation process, when integrated with blackwater and greywater reuse has great potential for implementation in Australia. The sustainability of water resources, the wastewater disposal systems and farming could all be improved by implementing urine separation in Australia. Reusing domestic wastewater in Australia would significantly contribute to water resource management, but also provide an opportunity to close the water and nutrient cycles.

A number of issues require further examination prior to the implementation of the urine separation process in Australia to ensure that it can be implemented safely and successfully.

It is the now the responsibility of the State Government and Regulatory authorities to take the initiative, however Public support is essential for successful implementation. It is hoped that the Western Australian people are receptive to the developing wastewater paradigms, and are willing to consider employing alternatives methods to aid in water conservation.

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APPENDIX 1.

The following inserts contain information about Wastewater Reuse Technologies.

APPENDIX 2.

The following insert is a poster outlining project aims.

An Emerging Paradigm in the Reuse of Domestic Wastewater: Urine Separation

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Introduction

The approach to water supply and disposal in developed nations is generally governed by a centralised strategy, an unsustainable process. This process often results in water being used at an unsustainable rate and disposal in a wasteful manner.

The objective of this study is to address sustainability issues related to wastewater treatment, disposal and reuse. The study will focus on how the emerging paradigm of urine separation and reuse can be integrated into a sustainable domestic water management strategy.

Rationale

- Wastewater transport, treatment and disposal methods contribute to significant waste of valuable water resources.
- Urine constitutes only 1% of the total household wastewater stream, yet it is the largest contributor of nutrients. Up to 80%of Nitrogen and 60% of Phosphorus in wastewater is from the urine portion (Jonssen, et al.,1998).
- The current methods of urine disposal breaks the cycle of nutrients that occurs in nature (Figure 1).

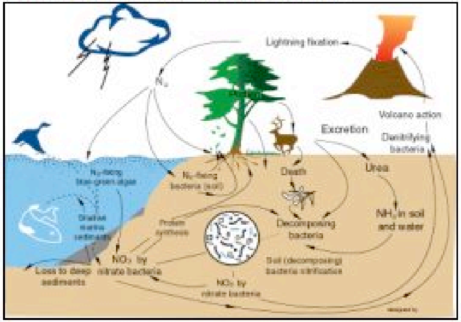

Figure 1: The Nitrogen Cycle

Discussion

Traditional disposal methods combine all domestic wastewater for treatment and final disposal. Much research has been carried out on sustainable technologies to treat and reuse the widely recognised wastewater fractions of 'blackwater' (toilet wastewater) and 'greywater' (wastewater from laundry, bath/shower and kitchen) however little study of the urine fraction has occurred in Australia..

Examining domestic wastewater only in terms of blackwater and greywater is now viewed by some as "narrow". Urine separation and reuse in agriculture has been successfully implemented in Europe for a number of years (Jonssen, et al.,1998).

Implementing urine separation and reuse in Australia may be technologically feasible, however the management and regulating issues require significant consideration.

Progress

Preliminary research results indicate that Australia, due to cultural similarities with Europe, can successfully adopt the urine separation process and employ reuse techniques.

Great potential exists to reuse the nutrients available in urine for fertilizer application in Australian agriculture. Urine separation technologies (Figure 1and 2) can be retrofitted to households, enabling collection and reuse.

Figure 2:
The Roediger 'No Mix' separation toilet, showing the separate collection basins.

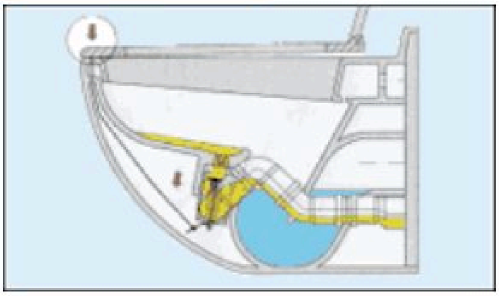

Figure 3:
The separation process

Conclusion and Further Research

With the threat of water shortages becoming increasingly important, there is a great need to develop and implement water saving technologies, such as the urine separation process, in Australia. Benefits obtained from the process extend from water conservation to reduced waterway eutrophication from chemical fertilizers and lower wastewater transport and treatment costs.

Further research is required in the areas of social acceptance, political management/regulation and reuse potentials. The development of a step-by-step process for implementation is also planned.

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