EXECUTIVE SUMMARY

Environment Canada is responsible for the classification of shellfish growing waters under the mandate of the Canadian Shellfish Sanitation Program (CSSP). This classification is based on water quality analysis (faecal coliform counts used as an indicator of the potential presence of pathogenic organisms) and shoreline pollution source investigations (potential sources of faecal contamination.

Floating accommodations (float-homes) associated with and located near commercial shellfish operations are a particular potential source problem along the British Columbia coast. Many of the shellfish leases are situated in remote locations without any shore-based wastewater treatment options or services. Areas in the immediate vicinity of the supporting float-homes are closed to shellfish harvesting due to discharge of sewage and greywater, in many cases representing a considerable loss in area of productivity (and revenue) to the lease holder. The size of the required closure area can be reduced to a minimum (25 m radius) provided there is no discharge of effluent at the lease site.

Environment Canada is seeking information on the various options available for handling and disposing of greywater generated on float-homes located in shellfish tenures, with particular interest in options that can potentially meet the zero discharge criteria. While there is considerable information available on technologies for handling sewage (ie, NovaTec 1999 report[1]), this information needs to be updated in light of recent advances in wastewater treatment and reuse technologies and water reuse standards. In particular, information is required on practical options available for handling and disposing of greywater from float-homes to meet the zero effluent within the tenure requirement.

There are two types or general sources of residential or domestic greywater: light-greywater (from bathroom sinks, showers, bathtubs and laundry) and dark-greywater (from kitchen sinks, containing organics and oil/grease). Regardless of source, residential greywater contains the same contaminants (but at different concentrations) as blackwater from toilets (including organics and pathogenic micro-organisms) and must be treated prior to reuse.

In British Columbia, wastewater discharged from single family dwellings is regulated under the Health Act - Sewerage System Regulation (SSR, 2004). However, the SSR specifically does not permit residential wastewater (including greywater) effluent discharges into marine waters. Such discharges in the province of British Columbia are regulated under the Waste Management Act - Municipal Sewage Regulation (MSR, 1999). However, the Waste Management Act exempts discharges from single family dwellings, placing floating home greywater (treated or untreated) effluent discharges into a potential regulatory limbo. The current regulations are also barriers to greywater reuse (i.e. use of treated greywater for such applications as toilet flushing). While clusters of two or more dwellings serviced by a common greywater treatment and reuse system are regulated under the MSR, there is no such provision under the SSR and the reclaimed water requirements under the MSR may be onerous for small floating home private systems.

Potential floating home greywater reuse applications include irrigation, toilet/urinal flushing, vessel washing, bathing/showering, and direct discharge. The most common domestic

[1] Report to BC Assets & Lands Corporation entitled "Wastewater Handling For Floating Cabins on Powell Lake".

applications (internationally) are subsurface irrigation (depth of at least two feet) and toilet flushing, the former of which is impractical for floating home applications. The type of reuse application dictates the level of treatment required.

Greywater reuse systems can be broken down into two basic categories: i) diversion/filtration (with direct application); and ii) biological treatment (with storage). Advanced secondary or tertiary treatment is required if reuse is to include bathing, showering, laundry or storage.

Costs for individual treatment systems vary greatly from $64 for a simple sink diversion system (with no treatment) up to $15,000 for a biological treatment system to provide full greywater reuse capabilities.

In general, cost for greywater treatment technologies will vary according to the complexity of the system, with the highest treatment costs usually associated with reuse applications. Costs for a complete reuse system include the capital and operating/maintenance cost of the treatment system, storage system and the pumping and dual plumbing system to deliver reuse water (as applicable). More complex treatment systems also have higher maintenance costs and normally require a skilled operator to maintain the system (under an annual contract with the homeowner).

Reduced wastewater discharges as a result of greywater water reuse applications will reduce both floating home discharges (and potential adverse environmental impacts) and potable water demands.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF PHOTOS

LIST OF TABLES

1 INTRODUCTION

This report focuses on the treatment and potential reuse of floating home residential greywater sources including bathtubs, showers, laundry, and sinks onboard.

Environment Canada is responsible for the classification of shellfish growing waters under the mandate of the Canadian Shellfish Sanitation Program (CSSP). This classification is based on water quality analysis (faecal coliform counts used as an indicator of the potential presence of pathogenic organisms) and shoreline pollution source investigations (potential sources of faecal contamination.

Floating accommodations (floathomes) associated with and located near commercial shellfish operations are a particular potential source problem along the British Columbia coast. Many of the shellfish leases are situated in remote locations without any shore-based wastewater treatment options or services. Areas in the immediate vicinity of the supporting float homes are closed to shellfish harvesting due to discharge of sewage and greywater, in many cases representing a considerable loss in area of productivity (and revenue) to the lease holder. The size of the required closure area can be reduced to a minimum (25 m radius) provided there is no discharge of effluent at the lease site.

Environment Canada is seeking information on the various options available for handling and disposing of greywater generated on float homes located in shellfish tenures, with particular interest in options that can potentially meet the zero discharge criteria. While there is considerable information available on technologies for handling sewage (ie, NovaTec 1999 report[2]), this information needs to be updated in light of recent advances in wastewater treatment and reuse technologies and water reuse standards.

This report outlines practical options available for handling and disposing of greywater from float-homes, with greywater reuse as a suggested option to meet the zero effluent objective within the tenure requirement. A brief description of the available treatment and disposal technologies is presented for greywater sources. Relevant information such as advantages, disadvantages, capital and operating costs, treatment requirements, operations and maintenance needs, treatment capacity and where possible, information on supplier/installer is also provided.

Greywater is generally treated using a variety of treatment technologies of varying sophistication, and can be renovated to a quality where it can be reused for other applications such as plant irrigation, washing, laundry, or toilet flushing. There are a number of available technologies to treat the greywater. A discussion of some of these technologies and their various components is presented later in this report.

1.1 Objectives & Purpose of this Document

From a practical perspective, there is no such thing as a zero discharge domestic wastewater treatment system. However, the volume of potential onsite discharges can be significantly reduced by incorporating water reuse technologies - potentially to the point where residual

[2] Report to BC Assets & Lands Corporation entitled "Wastewater Handling For Floating Cabins on Powell Lake".

effluent volumes can be economically stored and removed for subsequent discharge offsite. Alternatively, the water quality standards achievable through water technologies may be considered adequate to be equivalent to a zero discharge criteria from an environmental and health perspective taking into consideration management plans.

Water reuse strategies can result in a dramatic reduction in water demands and effluent discharge volumes, as well as improvements in the quality of the discharged effluent over that typically expected for secondary treatment. Health jurisdictions throughout the world are moving to adopt water reuse standards and criteria in response to global water shortages, and considerable knowledge has been advanced over the past five to ten years in this area.

The report includes commentary on the following related areas:

- Greywater definition;
- Current regulatory environment for greywater discharges and reuse in B.C.;
- Options for greywater treatment including components of treatment and reuse systems – collection, treatment, disinfection, storage and recirculation of disposal systems;
- Complexity and technical skills needed to operate greywater systems;
- Cost of greywater treatment and reuse systems – capital and operating costs;
- Case study summaries of existing greywater treatment and reuse installations and;
- Use of greywater systems for floating home applications.

1.2 What is Greywater?

Residential wastewater is a mixture of all water discharges within the household including toilets, kitchen sinks, bathroom sinks, bathtubs, and laundry wash-water sources. This wastewater is characteristically divided into three sub-categories related to the organic "strength" or level of contaminants typically contained in the water: 1) blackwater; 2) dark-greywater, and 3) light-greywater.

Blackwater comes from toilets and contains high concentrations of disease causing microorganisms and high levels of organic contaminants.

Dark-greywater primarily originates from kitchen sinks, which can also contain disease-causing microorganisms and have high levels of organics contaminants from food waste and grease/oils.

Light-greywater typically consists of drainage from bathroom sinks, tubs, showers, and often laundry. It can also contain disease-causing microorganisms but they are usually in much lower numbers than the other two wastewater categories. Although light-grey water is generally also considered to have lower concentrations of organic contaminants than the other two wastewater sub-categories, the level of organic contaminants can be comparable to the other two depending on the circumstances. Ignorance of this fact contributed to the cause of system failure in one of the case studies presented later in this document (see Conservation Coop Case Study).

Greywater may contain varying levels of disease-causing microorganisms that are washed off during bathing and from clothes during laundering, and may also contain fats, oils, grease, hair, lint, soaps, cleansers, fabric softeners and other chemicals. Soaps and detergents are biodegradable, but they can present problems when greywater is used over an extended period. The main problem with most cleaning agents is that they contain sodium salts which, if present in excessive amounts, can damage the soil structure, can create an alkaline condition. Elevated levels of chlorides, sodium, borax, and sulfates, and high pH (alkaline) characteristics of greywater may be harmful to some plants.

In considering the application of greywater reuse it should be kept in mind the kinds of chemicals that may end up being flushed down sinks including: kitchen and household cleaning products, washing detergents, soaps, shampoos and conditioners. These household products can contain a vast array of potentially harmful chemical contaminants that can affect the safety of greywater reuse applications (e.g. petro-chemicals, chlorine, caustics, animal ingredients, sodium lauryl sulfate, etc.).

Because all wastewater categories (i.e. black, dark-grey and light-grey water) contain some level of organic contaminants and potential disease causing microorganisms, they should all be given the same consideration with respect to public health risk and safety in considering treatment and reuse applications. Research has shown all greywater carries various levels of bacterial contamination (Ottoson and Stenström, 2002). Because light-greywater typically has low concentrations of organic and inorganic contaminants, and disease causing microorganisms, it can often be considered for direct reuse (without treatment to reduce the contaminants) for applications where there is low risk of public contact (e.g. toilet flushing) and storage is not required. In contrast both blackwater and dark-greywater both typically require treatment and at least some level of disinfection before they can be stored or safely used for reuse applications.

If biological treatment is required because of the need to store reuse-water, because of the level of contaminants present, or because of the desire to apply reuse water for applications in which human contact is likely, the treatment technology required is identical for both blackwater and greywater (i.e. secondary, advanced-secondary, or tertiary treatment with disinfection) and consideration should be given to treating the mixed wastewater stream rather than segregating, treating and reusing only the greywater portion. The biological (secondary) treatment systems described in Section 3.0 intended for use in greywater treatment are identical to the technologies marketed and used for mixed wastewater treatment applications.

Figure 1 illustrates a generic approximate proportion of daily wastewater flows generated by a household.

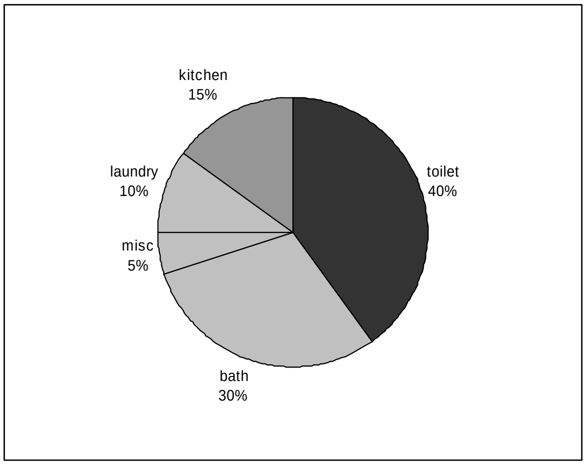

Figure 1 Breakdown of household wastewater by source (www.greywater.com)

1.3 Pros and Cons of Greywater Reuse for Floating Homes

Pros:

- The obvious key advantage of domestic greywater use is that it replaces or conserves potable water use, and can reduce the cost of potable water supply.
- Appropriately applied, greywater may contain nutrients (e.g. phosphorus and nitrogen from detergents), benefiting plant growth and resulting in more vigorous vegetation.
- Greywater can be used for toilet flushing and, if treated to an advanced secondary or tertiary level, can also be used for a wide range of domestic water uses including bathing, showering, and laundry.

Cons:

- Concern regarding the public health implications of greywater reuse, and the need for research to determine the risks of greywater reuse.
- Cost of treatment and diversion/transfer pipe & pumps.

2 INTERNATIONAL PERSPECTIVES

2.1 General

Until recently, greywater reuse applications within individual residential dwellings have not been given a great deal of consideration by regulatory authorities. Greywater treatment and reuse applications have often been carried out on a pilot or demonstration study basis without a regulatory framework, or have been carried out as a retrofit within a building without requiring significant plumbing modifications or related Permits. With the exception of illegal modifications made to plumbing without proper Permits, the prevailing attitude has been to ignore greywater reuse applications done within the privacy of the home and leave responsibility up to the individual homeowners. As a consequence of the lack of general regulatory interest, homeowners interested in greywater reuse have typically carried out their own research into appropriate reuse applications and alternative commercially available technologies or treatment equipment. The result is often a rather haphazard cobbling together of treatment components with little engineering input to how the components can best be integrated, and a high degree of operations and maintenance required to keep the systems functioning (see Quayside Village & Toronto Healthy House Case Studies).

While technology verification and certification standards and testing protocols exist for mixed wastewater residential wastewater treatment, none have been developed specifically for greywater treatment. Consequently, there is little information available to assess greywater technology manufacturers' claims, other than anecdotal testimony of other users, or reported in literature case studies.

2.2 Canada and the United States

In North America the lack of plumbing codes or other codes of practice have also forced homeowners interested in making modifications to their homes for greywater reuse to make such changes without Permits for household plumbing modifications, posing a potential risk of cross-contamination with potable water lines and connected community water distribution systems.

Many greywater reuse applications in North America tend to be one-of demonstration projects involving both passive (plant-based) and mechanical treatment technologies. Greywater Reuse is regulated in a number of US States including Arizona, New Mexico, California (since 1992), New Jersey, and Florida.

In New Mexico greywater is defined as "untreated household wastewater that has not come in contact with toilet waste and includes wastewater from bathtubs, showers, washbasins, clothes washing machines and laundry tubs, but does not include wastewater from kitchen sinks or dishwashers or laundry water from the washing of material soiled with human excreta, such as diapers" and up to 250 gallons per day of residential greywater to be used for household gardening, composting or landscaping irrigation without a permit, under specific conditions.

A study of 1,200 homes in 14 cities looking at residential water use found that the top four indoor uses were:

- Toilet (26.7 percent);
- Clothes washer (21.7 percent);
- Shower (16.8 percent);
- Faucet (15.7 percent).

Canada Mortgage and Housing Corporation (CMHC) has carried out most of the research and investigation work leading to greywater reuse demonstration projects in Canada, examining the potential for water reuse systems to contribute to water conservation planning and design practices associated with water management technology. CMHC has initiated several research and demonstration projects over the past nine years examining mechanical greywater reuse technologies and applications within residential settings. Two greywater reuse initiatives (Quayside Village, and Conservation Coop) are described in the case studies presented later in this report.

2.3 Europe

International interest in water conservation measures has resulted in a recent interest in implementing greywater reuse strategies within the home and the development of standards and regulatory codes of practice.

Many communities in Europe including Norway, Sweden and Denmark are using natural systems to treat their greywater (West, 2003). The following are examples of some of these initiatives:

2.4 Australia

Australia appears to be at the forefront of the move to implement greywater reuse as one of the key methods of residential water conservation.

In June 2004, Queensland State Cabinet endorsed the use of recycled water from showers and washing machines for use in garden irrigation following "extensive tests to ensure the untreated greywater will not pose a health hazard" (ABC News Online: Friday, June 4, 2004. 7:35pm (AEST)).

New South Wales (NSW) in Australia has initiated an ambitious Building Sustainability Index project called "BASIX", which is a web-based planning tool that assesses residential development proposals for a range of sustainability indices including landscape, stormwater, water, thermal comfort and energy (http://203.110.153.11/information/about.jsp). Building applicants are responsible for completing a BASIX assessment for each residential development proposal as part of the development approval process. The applicant enters information about a proposed development, such as site location, dwelling size, floor area, landscaped area and services, and the development is scored according to its potential to consume less water or energy than average existing dwellings.

Table 1 Potable water savings associated with various greywater reuse case studies in Australia (from Australian Water Association, April 2004)

Reference	*Location*	*End use*	*Tank description and size (kL)*	*% potable water reduction*
McAlister, 1999	Canberra, ACT	Irrigation & toilet flushing	Not stated	20%
Smith, 1999	Sydney, NSW	Irrigation & toilet flushing	Storage guttering (30 L of water/m)	27%
www.unisa.edu.au/water/prototypes/Regent_Gardens.html	Adelaide, SA	Hot water system & kitchen[1]	2 kL	30%[2]
Gardner et al., 2001	Gold Coast, Queensland	All household uses (with potable back-up)	22kL	32%
Apostolidis, 2003	Brisbane, Queensland	Laundry, toilet flushing and hot water supply	20kL	50%
Coombes, 2003(correct year?)	Newcastle, NSW	Irrigation, hot water system and toilet flushing	0.91kL	52%

[1] Ultra-violet disinfection system installed for kitchen uses
[2] Predicted value in combination with greywater

2.5 China

Beijing and Tianjin[3] have advanced municipal regulations for water reuse targeted at larger buildings (up to 30,000m^2)[4] that requires on-site greywater treatment and reuse systems. China's rapid economic growth (8 to 10%) has created a water crisis that the government is addressing through a number of policies, including regulations requiring greywater treatment and water reuse for larger scale institutional buildings and residential developments.[5]

The greywater treatment systems in use in China typically incorporate either activated sludge or fixed film (e.g. rotating biological contactor) biological treatment technologies, with limited operational success. While the laws require the provision of greywater reuse technologies, there has been no enforcement to verify their performance. The overall pragmatic objective is to conform to the laws and provide equipment at the lowest possible cost. The technologies often do not work. This is changing with as the regulatory authority's capacity to monitor performance increases.

[3] Tianjin already has a number of demonstration projects for commercial and industrial water reuse in place including a 12,000m^3/day *Meijiang residential district* for toilet flushing and garden watering, other projects include nursery irrigation, car washing and power plant cooling; as reported in: Xingcan Zheng *Research and Pilot Projects on Municipal Water and Wastewater Reclamation and Reuse in China*, National Engineering Research Centre, for Urban Water and Wastewater, Tianjin, China.
http://lnweb18.worldbank.org/ESSD/essdext.nsf/18ByDocName/ResearchandPilotProgramonMunicipalWastewaterReclamationandReuseinChina--PowerpointPresentation/$FILE/ZhengXingcanpresentationoutline.pdf
[4] Haifeng, J. et al, (2004) *Research on Wastewater Reuse Planning in Beijing Central Region*, Proceedings of the 1st International Conference on Onsite Wastewater Treatment and Recycling. Perth, Australia.
[5] The Chinese Ministry of Water Resources estimates that 400 of 658 cities are suffering from water shortages.

3 GREYWATER TREATMENT TECHNOLOGIES

3.1 Approaches to Greywater Treatment & Reuse

Greywater treatment approaches range from simple low-cost devices that route greywater directly to applications such as toilets and garden irrigation, to highly complex and costly advanced biological treatment processes incorporating sedimentation tanks, bioreactors, filters, pumps and disinfection systems.

There are a number of greywater systems commercially available, and they include one or more if the following components: primary solids separation, oil and grease removal, filtration, aerobic biological treatment, coagulation and flocculation, and disinfection. Some of these systems are able to remove pollutants and bacteria from greywater and the better systems include settling tanks, biological reactors and sand filters, enabling the treated greywater to be stored until needed without adverse conditions occurring (e.g., foul odours, corrosion, etc.)

3.1.1 Diversion Valves

A wide range of greywater treatment technologies exist of varying designs according to the level of treatment required and the intended reuse (water quality) application.

A diversion device is probably the simplest and most common method of greywater reuse. Diversion devices direct untreated greywater typically from laundry or bathroom sinks to a sub-surface garden irrigation system. Sub-surface drip irrigation systems minimize human contact with the greywater and, therefore, are one of the more common irrigation distribution methods for greywater. Rather than relying on gravity feed systems, some greywater diversion schemes drain greywater to a tank fitted with an effluent pump, which pumps the greywater to a sub-surface irrigation field. Where kitchen sinks are included in a diversion greywater system, a grease trap, screen and/or settling tank is used to separate out grease and large solids that would otherwise clog piping.

Pros:

- Simple manual (hand adjust or preset) operation
- Very low maintenance requirements (period manual screen cleaning).
- Ability to divert greywater for immediate reuse as required or desired.
- Very low capital and operating cost

Cons:

- No or limited (screening) treatment provided.
- Cannot store without risk of odour and other problems.
- Does not kill or reduce the number of disease-causing microorganisms (pathogens) that may be present.
- Reuse application typically limited to immediate sub-surface irrigation only.

3.1.2 Sand Filters

Sand filters usually consist of beds of sand or in some cases coarse bark or mulch, which trap and adsorb contaminants as the wastewater flows through it. "Sand filters', depending on the design, can have two treatment functions which are not necessarily inclusive: 1) physical filtration (separation) of particulate matter; and 2) biofiltration (i.e. intermittent or recirculating sand filters) which involves physical particulate separation, and the adsorption and biodegredation of soluble and particulate organic contaminants from the greywater.

If the sand filter is open at the surface and the flow rate is intermittent and/or low enough to maintain aerobic conditions (i.e. the supply of oxygen) for fixed-film bacteria to treat the greywater (i.e. intermittent or recirculating sand filter) the filter can provide biological treatment of the trapped organic material. Biological treatment in sand filters involves the breakdown of organics by bacteria and other microorganisms as well as snails, worms and insects.

If the sand filter is flooded but open at the surface (i.e. slow sand filter) less oxygen is provided to attached-growth bacteria and a lower level of biological treatment is expected.

If the sand filter is pressurized within a container, or subject to high flows (i.e. a sand filter typically designed for physically removing sediment and particulates for potable water treatment), and no oxygen source is provided, then no biological treatment is expected. Effluent from such greywater sand filter systems may be collected and redirected directly to either subsurface irrigation or toilet flushing, but should not be stored without first being biologically treated to remove soluble and particulate organic material. Storing greywater without first having been biologically treated can result in anaerobic (septic) conditions, and odours (see Conservation Coop case study).

The footprint required for sand filtration depends on the degree of biological treatment required or expected. For example, intermittent sand filters or recirculating sand filters will require significantly more footprint than a pressure-vessel style sand filter only providing physical filtration of particulates. Intermittent sand filters may require up to 400 square feet per household, whereas recirculating biofilters may require as little as 20 square feet.

Greywater should pass through a settling tank and possibly a grease trap or screen prior to treatment through a sand filter to reduce loading to the filter and avoid clogging. Properly designed, sand filtration systems have the ability to treat greywater to a high standard, with low maintenance and cost.

Although sand filters are not likely to be a practical solution for a floating home application, there are innovative biofilter designs commercially available that function on the same principles but use alternative materials such as foam rubber (Waterloo Biofilter) or textile fabrics (Orenco Advantex Filter, ADS Filter).

Pros:

- Simple operation.
- Low maintenance.

- Some biological treatment provided facilitating limited duration storage and increased application options than valve diversion alone.
- Low operating cost

Cons:

- Potentially incomplete biological treatment with no ability to adapt to varying greywater characteristics if not properly designed and sized.
- High capital cost.
- Reduces the number of disease-causing microorganisms (pathogens) that may be present, but does not eliminate them (i.e. does not disinfect).
- High footprint requirements for biological treatment in comparison to alternative mechanical-based biological treatment systems (not likely suitable for application for a floating home.
- Subject to clogging and flooding if overloaded.

3.1.3 Aerobic Biological Treatment Systems

Aerobic biological treatment of greywater characteristically results in a better effluent quality than achievable with single-pass or slow sand filtration. The greywater may be discharged into a tank in which air is bubbled to transfer oxygen from the air into the liquid. Bacteria present in the greywater consume the dissolved oxygen and digest the organic contaminants, reducing the concentration of these contaminants and, in turn, also producing more bacteria. The air bubbled into the tank also provides mixing energy to keep the bacteria from settling.

Some aerobic treatment systems include support media (usually corrugated plastic sheets or suspended extruded plastic segments) for bacteria to attach to and grow on. The support media may be completely immersed in an aerated tank, sprayed with greywater (oxygen is passively dissolved into the liquid as it trickles over the media), or the media may be cyclically suspended in the air (to supply oxygen) and then immersed in liquid (to supply food).

One common method of cycling media through air and liquid is a rotating biological contactor (RBC), which consists of a series of large parallel discs that are rotated on a common shaft such that half the disk is immersed in liquid (food) while the other half is exposed to the air (oxygen). The discs are slowly rotated through the greywater.

Aerobic treatment systems typically are followed by a clarification stage to remove the suspended bacteria, and may be preceded by a septic tank to settle solids and remove oils & grease. Depending on the reuse application, the treated effluent may also be disinfected prior to use or storage to kill bacteria, viruses and other disease causing microorganisms. Common disinfection methods include chlorine, ultraviolet light, and ozone.

Pros:

- Potential for high degree of biological treatment.
- Less area required for treatment than biological sand filter systems.

- High degree of operations flexibility to accommodate varying greywater strengths and flows.
- Suitable for treating mixed wastewater for reuse applications if effluent is filtered and disinfected - which also allows the reuse water to be stored.

Cons:

- Complex operational requirements.
- High operating cost.
- High capital cost.
- Can be subject to process upsets due to high greywater flows or chemicals present, resulting in poor effluent quality or discharge of large quantities of solids (sludge) that may block downstream irrigation pipe or create problems for reuse applications (e.g. sludge or sediment buildup in toilet tanks, reduced disinfection effectiveness etc.)
- Greater amount of operation and maintenance than for other treatment systems.

3.1.4 Electro-coagulation

Electro-coagulation involves adding coagulating metal ions to the greywater using electrodes. These ions coagulate the contaminants in the water, similar to coagulating chemicals such as alum and ferric chloride, enabling them to be more easily removed by settling or floating (fine bubbles – dissolved air flotation {DAF}).

Pros:

- Non-biological treatment therefore is not necessarily adversely affected by chemicals that would otherwise upset a biological process.
- Typically less footprint required in comparison to biological treatment.
- Does not rely on gravity settling (clarifier) to remove particulates.
- Suitable for treating mixed wastewater for reuse applications if effluent is filtered and disinfected - which also allows the reuse water to be stored.

Cons:

- Complex operational requirements.
- High operating cost for power and replacement of electrodes.
- High capital cost.
- DAF may not operate efficiently.
- Chemicals often required, resulting in high operations and maintenance requirements.
- Typically, greater amount of operation and maintenance required than for other equivalent biological treatment systems.
- May not remove organic contaminants adequately to permit significant storage, which in turn would restrict reuse applications.

- Not commonly used to treat residential greywater, and there is limited operating experience available.
- May generate hydrogen gas which is highly explosive

3.1.5 Disinfection

Disinfection may be achieved using chlorine, ozone, or ultraviolet light. The most common and simplest method of disinfection is chlorination, usually achieved in greywater systems using sodium hypochlorite “pucks” similar to that used in disinfecting swimming pool water. Ozone is another means of chemical disinfection, typically generated onsite using a device that applies a high voltage-potential to air, and bubbling the ozonated air through the treated greywater. Finally, disinfection using ultraviolet light is becoming increasingly popular, as no chemicals are required and there is no chlorine residual that is harmful to aquatic life if discharged to receiving waters.

Chlorine Pros:

- Low operator skill requirement.
- Highly effective if properly designed and operated.
- Low capital cost.
- Typically lower operating cost for chemicals and operator O&M than ozone or U.V. technologies.
- Provides a residual disinfectant to ensure reuse water remains disinfected during prolonged storage.

Chlorine Cons:

- Chlorine reacts with residual organic contaminants to form potential carcinogens.
- Chemical handling requirements.
- Effluent must be dechlorinated before being discharged into marine waters.

Ozone Pros:

- Limited operator skill level required.
- No chemical storage or handling requirements (ozone generated onsite).
- Eliminates colour and precipitates residual contaminants.
- Typically less maintenance than U.V. systems.

Ozone Cons:

- Disinfection efficiency adversely affected by variations in organic content of greywater and flows.
- Ozone is toxic and off-gas must be destroyed.
- Results in a precipitate that must be subsequently removed.

- Higher operating cost than chlorination systems for operator attention and electricity.
- Higher capital cost in comparison with chlorination or U.V. systems.
- No disinfection residual.

Ultraviolet (UV) Pros:

- Low operator skill level required.
- No chemical storage or handling requirements (ozone generated onsite).
- No off-gas or chemicals to handle.

Ultraviolet (UV) Cons:

- Disinfection efficiency adversely affected by variations in organic content of greywater, flow and colour (UV absorbance).
- Adversely affected by particulates present in the treated water.
- Higher operating cost than chlorination systems (electricity & cleaning maintenance).
- Higher capital cost in comparison with chlorination systems.
- No disinfection residual.
- U.V. lamp tubes are subject to biological growth and chemical coating phenomena that interfere with U.V. transmission and disinfection, requiring the lamp tubes to be regularly cleaned to ensure effective performance.

3.2 Diversion Technology Suppliers

3.2.1 Clivus Multrum

Description:

The Clivus Multrum greywater irrigation system consists of a dosing basin, effluent pump, water level controls, and covered irrigation troughs (Figure 2). Greywater flows into the dosing basin. Once the liquid level is high enough level controls in the dosing basin engage the effluent pump, which pumps greywater to irrigation troughs and distributes the greywater evenly to the surrounding vegetation. Water, soap residue, and the small organic particles carried in greywater are discharged directly to plant roots and soil organisms, which consume the organic biodegradable contaminants and adsorb other inorganic and non-biodegradable components of the greywater.

Contact information:

Clivus Multrum, Inc.
15 Union Street Lawrence, MA 01840
toll free: 800-425-4887
phone: 978-725-5591
fax: 978-557-9658
http://www.clivusmultrum.com/greywater.html

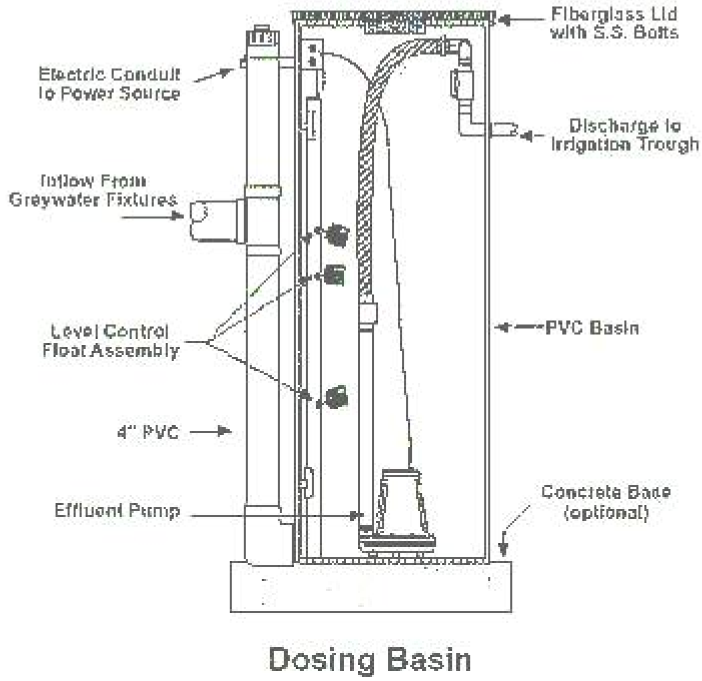

Figure 2 Clivus Multrum Dosing Basin (from http://www.clivusmultrum.com/greywater.html)

3.2.2 Envirosink®

Description:

Shown in Photo 1, Envirosink consists of a white plastic funnel that drains any discharge into it directly to a greywater system (treatment or direct use). The funnel is typically installed over one of the sink holes. The user determines what liquid is suitable for greywater reuse and what needs to be discharged to sewer. The greywater capture is achieved by swinging the tap over the Envirosink funnel, or by using a bowl to capture the greywater and then pouring it into the Envirosink.

The Envirosink retails for approximately $75.

Contact information:

Envirosink Canada
8584 - 145A Street
Surrey, B.C. V3S 2Z2
Canada
Tel: 888-663-4950
FAX: 604-591-8510
E-Mail: bismart@envirosink.com
http://www.envirosink.com/about.html

Photo 1 Envirosink (white funnel in photo) (from http://www.joneakes.com/ca/hs/cgi-bin/getdetailscahs.cgi?id=1975)

3.2.3 Greywater Saver

Description:

Similar in concept to the Envirosink, the Greywater Saver (Photo 2) consist of a manually operated gate valve, which users can open or close to select whether their greywater is diverted for garden irrigation or disposed to the sewer or onsite wastewater system. The Greywater Saver has a removable stainless steel mesh filter basket that is used to filter out larger particles from the greywater such as lint and hair. The stainless steel mesh filter can be removed for regular cleaning through the unit’s removable gas-tight screw cap access cover.

Filtered greywater flows by gravity from the device through 50mm diameter pipes to irrigation trenches (90mm diameter pipe with 20mm holes, surrounded by rock aggregate), which are located just beneath the surface of garden beds. An even distribution of filtered greywater to each of the piped irrigation trenches is achieved using Greywater Saver Flow Splitter 50mm diameter Y-junction fittings. These fittings are specially designed to split a single stream of filtered greywater under gravity into two equal volume streams.

The device costs about $500, plus the costs of installation ($300) and ground dispersal system (an additional $700).

Photo 2 Greywater Saver (from http://www.ecologicalhomes.com.au/econewsFeb04.htm)

<u>Contact information</u>:

Postal Address:
Post Office Box 7082,
Spearwood. W.A.
6163
phone mobile: 040 331 9410
Fax: 08 9467 6154
http://www.greywatersaver.com/contact.htm
e.mail: sales@greywatersaver.com

3.2.4 Aquatron Separator

Description:

The Aquatron Separator system (illustrated in Figure 3), can be used with standard toilets (flushing volume 3-6 litres) or special toilet models where the urine is mechanically diverted from the flushing water and the solid waste in the bowl itself. When the toilet is flushed, the contents of the bowl are transported to the **Aquatron Separator** where the solids are separated from the liquid using the momentum of the flushing water, centrifugal force and gravity. Solid waste (paper and faeces) falls down into a Bio-Chamber where the solids are digested (composted) by bacteria and (optionally) worms. Approximately 300 worms may be placed into the Bio-Chamber to start the process. Freezing will kill the worms, and the optimal temperature for composting is 12-25 degrees Celsius. The Bio-Chamber is ventilated and the digested solids may be added to garden compost or directly to soil in the garden depending on the degree of decomposition.

The liquid is treated by ultra violet light to kill bacteria and viruses, before being reused.

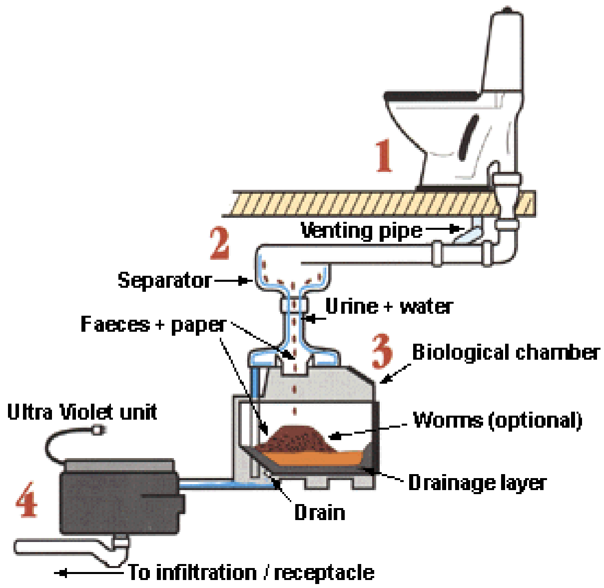

Figure 3 Aquatron Separator (from http://www.aquatron.se/start.au.html)

Contact Information:

Mail:
Box 2086
SE-194 02 Upplands Väsby, Sweden
Phone: +468 590 304 50
Fax: +468 590 304 94

3.3 Filtration Technology Providers

3.3.1 Nature Clear "Nature Loo"

Description:

Nature Clear "Nature Loo" greywater treatment system consists of a filtration tank, just under 1 cubic metre in volume, which is filled with pine bark lying on top of a fine sand filter. The pine bark provides coarse filtration of large particles such as grease particles or lint from laundry. The sand filter traps finer particles and polishes the water by reducing the organic content of the water. The pine bark is separated from the sand by filter cloth. The filtered material and bark will compost over time and needs to be removed every six months and replaced with fresh bark. Filtered greywater is then discharged directly to an irrigation trench or other greywater application.

In order for the filtration tank to work effectively, it is best to remove food scraps and grease from the kitchen greywater, and a grease trap is required to ensure the filter does not become clogged with grease.

The Nature Clear Filtration Tank costs about $750 excluding sand and pine bark.

Contact Information

PO Box 2157
Toowong (Brisbane) QLD 4066
Australia
Phone: +61 (07) 3870 5037
Fax: +61 (07) 3870 5088
Email: info@nature-loo.com.au
http://www.nature-loo.com.au/greywater/natureclear/natureclear.html

3.3.2 Biolytix "Grey Water Recycler"

Description:

The Biolytix Filter separates the organic matter from the greywater and enables microorganisms to aerobically digest the organic material trapped by the filter (Figure 4). The layered filter collects the organic material at the top surface, allowing the water to filter down through the filter and be pumped from the bottom. Filtered greywater is then pumped directly to a reuse application.

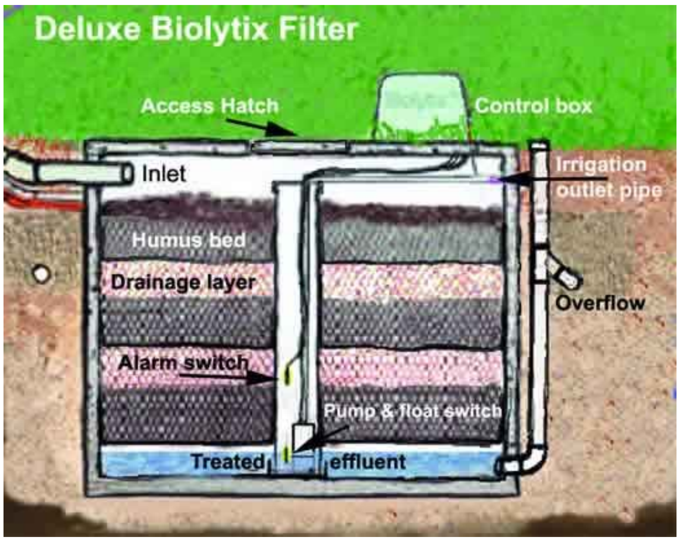

Figure 4 Biolytix Filter (from website: http://www.biolytix.com/filtration)

Contact Information:

Biolytix Technologies Pty Ltd -
Sales & Product Information: 1300 881 472
Phone: 07 54352700 - Fax: 07 54352701
PO Box 591, Maleny, Queensland, Australia 4552 ABN: 11 097 798 966
http://www.biolytix.com/filtration

Email: info@biolytix.com

3.4 Aerobic Biological Treatment

3.4.1 Go-Green"

Description:

The Go-Green system consists of a series of tanks that carry out advanced secondary and tertiary biological treatment using a fixed biofilm process (Figure 5). The process is designed to treat wastewater and greywater to an advanced level (i.e. BOD_5 < 10 mg/L and TSS < 10 mg/L), in addition to complete nitrification (conversion of ammonia to nitrate) and (optionally) partial dentirification (nitrogen removal). Applicable for treating either mixed wastewater or greywater, the system includes the following components :

1) Solids removal chamber (coarse solids, grit and grease/oil separation);
2) Anaerobic fermentation chamber;
3) Aerated biofilm (attached growth media - plastic) reactor;
4) Secondary solids clarification & effluent filtration;

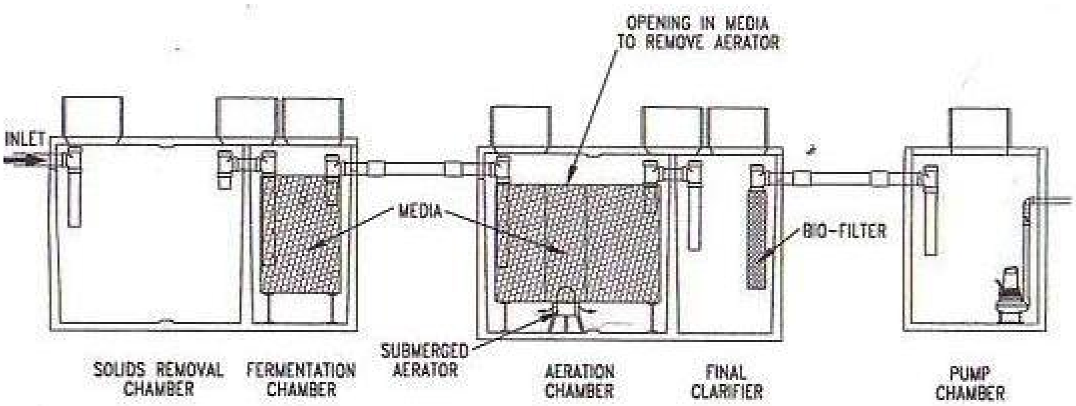

Figure 5 Go-Green Process Diagram

One unique aspect of this technology is that it has been scaled and applied in British Columbia to marine vessel and houseboat wastewater and greywater treatment applications with water reuse (See Go-Green Case Study).

Contact Information:

Phone:
Tel: 604-657-2724
Fax: 604-468-7333
http://www.gogreenwastewater.com/index.html
by e-mail...go_green@telus.net

3.4.2 AquaClarus "Simply Natural"

Description:

The AquaClarus "Simply Natural" treatment system consists of a 3 m^3 tank that is connected to a vegetation cell and subsurface effluent dispersal trenches (Figure 6). The treatment tank is filled with alternate layers of coarse and fine media, and bacteria that become attached to the media are provided oxygen through passive ventilation. The liquid passing through the treatment tank is collected in a chamber, and is periodically recirculated back onto the media. When the liquid in the chamber reaches a specific level, a pump is activated that transfers the treated effluent to the soil dispersal trenches. The manufacturer refers to the media filled treatment tank as a "vertical wet composting / decomposition chamber. Solids accumulating in the treatment tank are broken down by bacteria and digested by worms and other invertebrates. The resulting worm manure (vermicast) is periodically pumped with a small amount of liquid to the vegetation cell, where it provides nutrients for the plants. The manufacturer plans to release an upgraded product in 2004 called the "Super Natural" which will allow the treated water to be reused for irrigation and other domestic reuse applications.

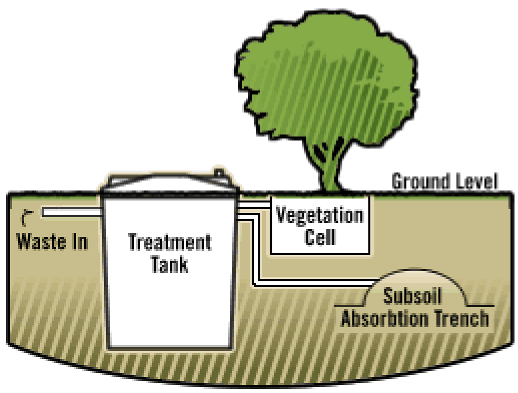

Figure 6 AquaClarus "Simply Natural" System (from website: http://www.aquaclarus.com/prod_sim_how.htm)

Contact Information:

Phone:
Sydney Office: 1300 368 158
Brisbane Office: (07) 3804 1522
fax.:
Sydney Office: 1300 368 058
Brisbane Office: (07) 3804 1533
http://www.aquaclarus.com/prod_sim_how.htm
by e-mail...info@aquaclarus.com

3.4.3 Equaris Greywater Treatment System

Description:

The Equaris greywater treatment system (illustrated in Figure 7) is an activated sludge process in which greywater is drained to a series of tanks including: 1) a surge tank for flow control, 2) an aeration tank to biologically digest organic material under aerobic conditions; and 3) a clarification tank to settle bacteria generated in the aeration tank and transfer the settled biosolids back to the surge tank. An air compressor provides oxygen and mixing energy to the aeration tank by bubbling air through liquid in the tank.

The estimated treatment capacity of the Equaris greywater treatment system is 250 gallons per day (0.95 m^3/d).

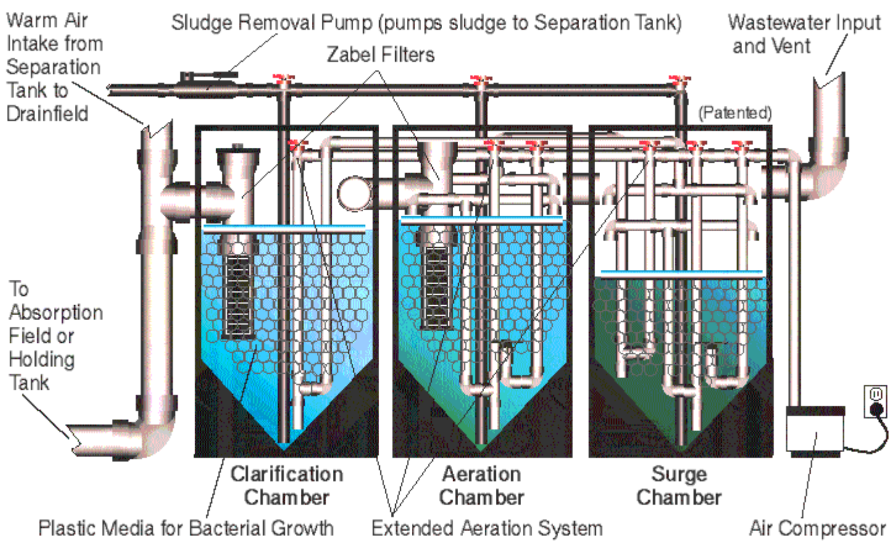

Figure 7 Equaris Greywater Treatment System (from: http://www.alascanofmn.com/default.asp?Page=Wastewater)

Contact Information:

Equaris Corporation
15711 Upper 34th Street South
P.O. Box 6
Afton, MN 55001-0006
Phone: 651-337-0261
Fax: 651-337-0265
mail@equaris.com
http://www.alascanofmn.com/default.asp?Page=Wastewater

3.4.4 Clearwater Treatment System

Description:

The ClearWater greywater treatment system is similar in concept to the Aquaris system and consists of three chambers or tanks in series. The system is an aerated activated sludge process that includes a primary solids separation tank, an aerated biological treatment tank to digest organic contaminants, and a final clarification tank to settle generated bacteria and transfer the biosolids to the primary solids separation tank. The process has a nominal treatment capacity of 250 gallons per day (0.95 m^3/d), and has a minimum hydraulic retention time of 18 hours.

Contact information:
AlasCan of Minnesota, Inc
8271 90th Lane, PO Box 88
Clear Lake, MN 55319
(320) 743-2909
(320) 743-3509
http://www.epa.gov/region1/assistance/ceitts/wastewater/techs/clearwater.html

3.4.5 Copa MBR Technology®

Description:

The Copa MBR Technology® (shown in Photo 3) is an aerobic biological treatment process that incorporates Kubota flat sheet membranes within a stainless steel tank which is subjected to coarse bubble aeration. The membrane panels have a nominal pore size of 0.1 to 0.4 microns that in operation become covered by a layer of cellular material that further enhances the filtration. The treatment process produces a high quality biologically treated effluent that is well suited for effective disinfection with ultraviolet radiation.

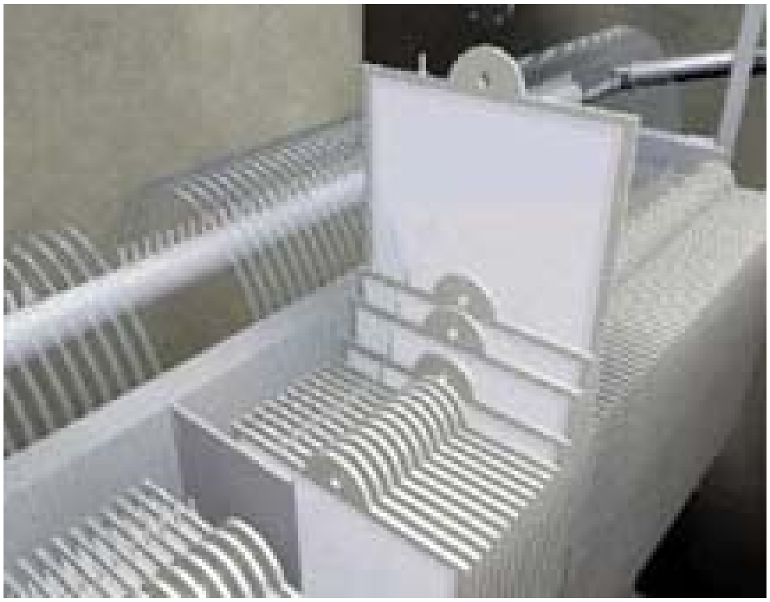

Photo 3 Kubota Flat Sheet Membranes (from http://www.copa.co.uk/products/mbr/default.asp)

Contact information:

Head Office: Copa Ltd.
Crest Industrial Estate
Pattenden Lane
Marden
Tonbridge
Kent
TN12 9QJ
Tel: +44 1622 833900
Fax: +44 1622 831466
http://www.copa.co.uk/products/mbr/default.asp

3.4.6 Wasser Recycling Solutions

Description:

Greywater is collected separately from blackwater and then treated by a rotating biological contactor (RBC) biological treatment system. The Water Recycling Solutions RBC (see Figure 8) consists of polyethylene sheets that are rotated into the liquid. Attached growth bacteria are cyclically immersed in the greywater (providing food) and then exposed to air (oxygen). The attached bacteria eventually fall off of the polyethylene sheets and are removed in a secondary settling tank. The biologically treated greywater is then disinfected using UV-radiation and stored in a service water tank. The storage tank is automatically replenished with drinking water when the service water is in short supply.

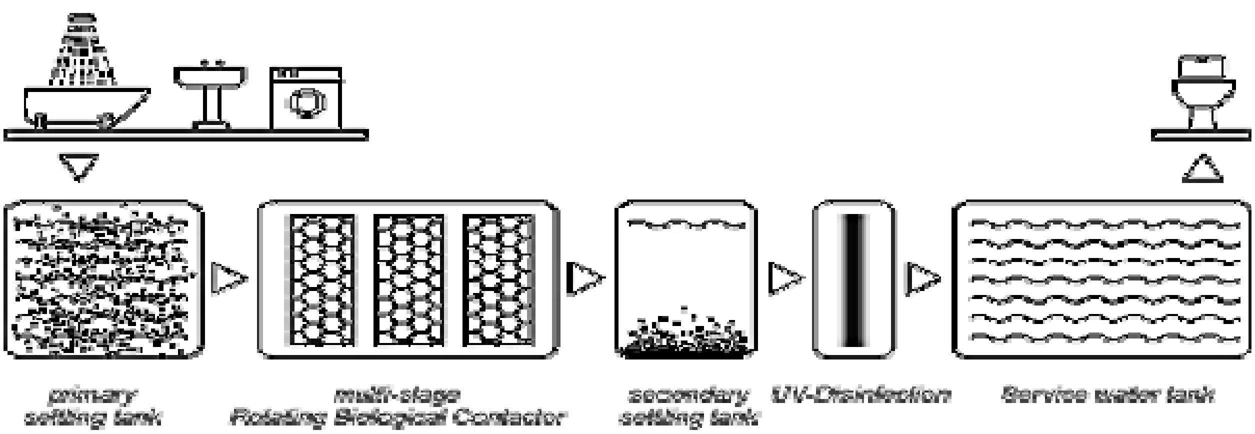

Figure 8 Wasser recycling Solution (from http://www.greywater.com/e_s2_konzept.html)

Contact Information:

http://www.greywater.com/e_s2_konzept.html

3.5 Flocculation & Coagulation

3.5.1 Electropure Greywater Treatment System

Description:

In the Electropure system, electrodes are used to pass an electric current through the greywater inside a reactor releasing metal ions and gas bubbles. The metal ions precipitate contaminants in the greywater, and the gas bubbles float the precipitates to the surface of the tank where they are skimmed off and removed.

Contact information:

Electropure International Pty Ltd
242 Canterbury road
Canterbury NSW 2193
Australia
Phone:
+61 2 9787 6333
Fax::
+ 61 2 9718 8222
E-mail:
info@electropure.com.au
http://www.electropure.com.au/techinfo/index.html

3.6 Disinfection

3.6.1 Chlorination

3.6.1.1 Chlorine Dioxide -ERCO™ Chlorine Dioxide Technology

Description:

The ERCO™ system uses chlorine dioxide to disinfect effluents. Chorine dioxide is a yellowish-green gas that is typically generated onsite. Although chlorine dioxide is unstable as a gas (decomposing into chlorine gas, oxygen gas, and heat) it is soluble in water and is stable as an aqueous solution.

Contact Information:

Information Request Coordinator:
Sherrie Tack
ERCO Worldwide
302 The East Mall,
Suite 200 Toronto, Ontario,

Canada M9B 6C7
Telephone: 416-239-7111
Fax: 416-239-8091
http://www.clo2.com/index.html

3.6.1.2 Blue Crystal Residential Disinfecting Calcium Hypochlorite Tablets

Description:

Blue Crystal disinfecting tablets are composed of calcium hypochlorite. The tablets provide a simple means of disinfecting treated effluents over the wide range of flow rates that are common to residential systems. The tablets are conveniently dispensed using a tablet feeder, or stacking tube. As the calcium hypochlorite tablet at the bottom of the tablet feeder is dissolved into solution, it is replaced by the tablet stacked above it.

Contact Information:

Norwalk Wastewater Equipment Company, Inc.
220 Republic Street Norwalk, Ohio U.S.A. 44857-1196
Phone: (419) 668-4471 Fax: (419) 663-5440

3.6.2 Ozonation

Description:

Ozone is generated by passing air across a high voltage source. Ozone is a very reactive form of oxygen that can oxidize a wide variety of contaminants and microorganisms. Unlike chlorine, ozone does not produce any toxic by-products. Ozone has high oxidizing power and is an effective disinfectant that is generated onsite.

Photo 4 OzoMax Residential Ozone Generator (from http://www.ozomax.com/ozonator.htm)

Contact Information

OZOMAX LTD
600 Robitaille
Granby, Quebec
Canada J2G 9J6
Phone: (450) 378-6825
Fax: (450) 777-0264
E-mail: Ozomax Ltd

WEDECO Ozone Technologies
North America
14125 South Bridge Circle
Charlotte, NC 28273, USA
Tel. 704-716-7600
Fax 704-716-7610

3.6.3 Ultraviolet Light

Description:

Ultraviolet (UV) disinfection technology is a proven solution for contamination from harmful microorganisms including bacteria, viruses, spores, and cysts. UV systems transfers electromagnetic energy from a mercury arc lamp to an organism's genetic material (DNA and RNA). When UV radiation penetrates the cell wall of an organism, it destroys the cell's ability to reproduce.

UV disinfection is a physical process rather than a chemical one, and there is no residual effect that can be harmful to humans or aquatic life. UV technologies are relatively easy for homeowners to use as there is no need to generate, handle, transport, or store toxic/hazardous or corrosive chemicals. However, they are also adversely affected by turbidity and total suspended solids (TSS) in the wastewater that can be the result of poor operator attention or servicing.

Contact Information:

Trojan Technologies Inc.
Head Office (Canada)
3020 Gore Rd, London, Ontario, Canada, N5V 4T7
Tel: (519) 457-3400, Fax: (519) 457-3030
Email: info@trojanuv.com

WEDECO UV Technologies
North America
14125 South Bridge Circle
Charlotte, NC 28273, USA

Tel. 704-716-7600
Fax 704-716-7610
http://usa.wedeco.de/Consumer___Residenti.278.0.html

3.7 Summary of Technologies

Table 2 provides a summary of the foregoing range of greywater treatment technologies and their components. Costs shown for individual treatment systems vary greatly ranging from $64 for a simple Envirosink system to $15,000 for the more complex Equaris system. In general, cost for greywater treatment technologies will vary according to the complexity of the system, which is usually related to the intended reuse application.

MANUFACTURER	no treat-ment	Filtration				Secondary Treatment				Disinfection	Disposal			Cost
						Biological			Physical					
		pre-liminary	sand-filter	natural	compost	Primary Tank	fixed film	suspended growth	electro-flocculation	Ultraviolet Light	irrigation	toilet flush water	laundry	
Clivus Multrum	X										X			
Envirosink	X													$64
Greywater Saver		X									X			$1,200
Aquaclarus		X			X						X	X	X	
Nature loo		X	X								X			$1,100
Biolytix				X							X			$5,500
Go-Green						X	X	X		X	X	X		$8,000 - $15,000
Equaris						X		X						$15,000
Clearwater								X						
Copa MBR		X					X			X				
Wasser		X				X	X			X				
Electropure									X					

Note: the costs indicated are the approximate cost of the treatment system and does not include installation of the system or installation of the disposal system, or the operation and maintenance cost of

*** Note costs are presented only for those technologies which either publishes such information or where the cost information was presented in the literature.**

4 CASE STUDIES

A brief literature search was made looking for floating home or vessel-based greywater treatment applications. Aside from the Go-Green Wastewater Systems described

4.1 Mt. Hawthorn, Western Australia

The Mt. Hawthorn greywater system in Western Australia is very new, and its characteristics are not yet well understood. The greywater from the laundry is filtered and used directly in the gardens. The system employs a basic filter-bag and an overflow pipe. The bag reduces suspended solids by 50%, and the data (Table 2) indicates there may be some nutrient reduction; however, as the system is very new, more testing is required. The expected daily flow for this device is 157 L a day.

Table 2 Mt. Hawthorn performance data.

Parameter	Inlet (to Filter)	Outlet (to trench)
Nitrate mg/L	3.8	2.5
Phosphate mg/L	0.09	0.06
Suspended Solids mg/L	155	76
Total Dissolved Solids mg/L	0.9	0.9
pH	7.8	7.6

4.2 GRS tank system, Western Australia

The bathroom and laundry greywater is directed to a 1000 L sedimentation tank (essentially a septic tank intended to remove any settleable particulate material from the greywater). The settled greywater is then immediately sent to a distribution system that provides water to a small fruit tree orchard. It also employs an overflow system and a diverter, to allow the owner to divert greywater to and from the distribution system. There are many systems like this installed around WA. The maximum daily flow for this device is 400 L per day. The reported performance characteristics are indicated in Table 3.

Table 3 GRS Tank System Performance Data.

Parameter	Inlet (to tank)	Outlet (to trench)
Nitrate mg/L	9.1	3.1
Phosphate mg/L	0.61	0.15
Suspended Solids mg/L	405	100
Total Dissolved Solids mg/L	1.0	1.2
PH	9.1	8

4.3 Double Tank System, Western Australia

Laundry and bathroom greywater is first passed through two sequential 350L sedimentation tanks (to remove settleable particulate material) followed by interim storage consisting of three (3) 200 L tanks linked to also serve as a pump chamber. The greywater pumped from the three 200 L tanks is filtered through a 25 mm in-line filter and distributed to the ground by a dripper system. Characteristic performance data published is shown in Table 4.

Table 4 Double Tank System Performance Data.

Parameter	Inlet (to tank)	Outlet (pump tank)	Dripper irrigation
Nitrate mg/L	3.3	3.0	1.7
Phosphate mg/L	1.93	1.63	0.66
Suspended Solids mg/L	310	195	20
Total Dissolved Solids mg/L	1.7	1.0	1.0
PH	10.3	8.9	8.2

4.4 East Bay, California

Two sites were selected through a survey of 500 people for implementation of an experimental greywater system. The system employed a 1/2 horsepower submersible pump, a 55-gallon surge tank, a sand filter, a subsurface drip system, a water meter and plumbing connections. The grey water systems each collected from two bathroom washbasins and two bath/shower drains and a laundry machine for use in irrigating a yard at one location and a shrub garden at the other. Each system cost about $1250 USD and labour cost for each was around $4150 USD. The labour costs were high due to the work involved in setting up the secondary piping system. The soil and gardens at each location were monitored and no noticeable negative impacts were noted.

The residents experienced no maintenance problems during the study, and both planned to keep the systems. They noted however that a significant financial incentive would have been required for them to purchase the system.

http://www.oasisdesign.net/faq/SBebmudGWstudy.htm

4.5 Casa del Agua (Tucson, Arizona)

Casa del Agua is a Tucson residence that was retrofitted in 1985 with water-conserving fixtures and reuse technologies, and landscaped with drought tolerant plants (see Photo 5). It is an occupied domestic residence that is also an educational project designed to facilitate research and to test domestic water use and conservation strategies, and is open to the public during scheduled hours. Compared to a typical Tucson home, municipal water consumption is reported to have achieved a 27% reduction in total water use and a 47% reduction in municipal water use as a result of the rainwater harvesting, greywater reuse, and desert-adapted landscaping with drip-irrigation and low-water-use fixtures used in the home (J. Am. Water Resour. Assoc., Vol. 37, no. 5, pp. 1237-1248. Oct 2001).

The Casa del Agua greywater system drains greywater from the household's water-using appliances into a 55-gallon sump surge tank. A filter is fitted over the greywater drain line where it enters the sump to remove lint and hair before the water is pumped to other components of the recycling system. The sump fills to a level that activates a float switch and then the greywater is pumped through an underground drip irrigation system to the landscape or for use in toilet flushing.

Construction of the Casa del Agua's greywater treatment and distribution system was about US$1,500. The 5,000 gallon volume storage tank cost about US $2,500.

http://ag.arizona.edu/AZWATER/arroyo/071rain.html

Photo 5 Casa del Agua demonstration project in Tucson, Arizona (from http://www.csbe.org/Brittain/brittain_fig1.htm)

4.6 Quayside Village, North Vancouver, B.C.

Quayside Village (QV) is a co-housing community located in the City of North Vancouver, British Columbia, which included a greywater recycling system in its design in cooperation with the North Shore Board of Health and the City, with financial support from the Canada Mortgage and Housing Corporation (CMHC).

As a multi-agency supported demonstration project, Quayside's greywater system had to be reviewed and discussed with a number of government agencies. The support of CMHC and the North Shore Board of Health has provided some degree of liability shelter for the City of North Vancouver in approving the project. However, municipal staff remained concerned about possible liability for water-related sickness. For this reason, only a very conservative system with many backup features was allowed, and the City would only allow the treated greywater to be reused to flush toilets.

Treatment Process Description

The wastewater treatment and reuse system, as initially installed included the following components (Figure 9):

1. Septic tank to remove coarse solids and grease/oil.
2. Biofilter (Waterloo™) with recirculation back to the septic tank inlet.
3. Slow sand filter to remove solids.
4. Ozone generator and contact tank.
5. Slow sand filter (automatically back-washed).
6. Storage tank

Process Performance

Although the system has been in operation for over three years, there are ongoing concerns about the (liability) risks involved in greywater recycling. While monitoring data indicates the water reuse system can meet the target water quality objectives, there have been a number of equipment failures that have interfered with being able to meet the regulatory requirements for six continuous months. One of the key problems initially identified was the reliance of ozone as the sole means of disinfection, compounded by the lack of adequate ventilation of the ozone off-gas. A result of poor design, the ozone was allowed to off-gas from the storage tank directly into the enclosed equipment room.

Changes to Improve Performance

Following a recent independent process review, the following remedial measures were implemented to improve system performance and address the problems observed with the Quayside Village reuse water treatment system:

- The ozone generator and contact tank were removed and replaced with a chlorination system. This eliminates the problems with the ozone off-gas and provides a chlorine residual to control re-growth of bacteria.
- The cloth fabric was removed from the septic tank. The supplier intended the fabric to assist in removing colloidal particles; however, the structure supporting the fabric in the tank collapsed and blocked the outlet.

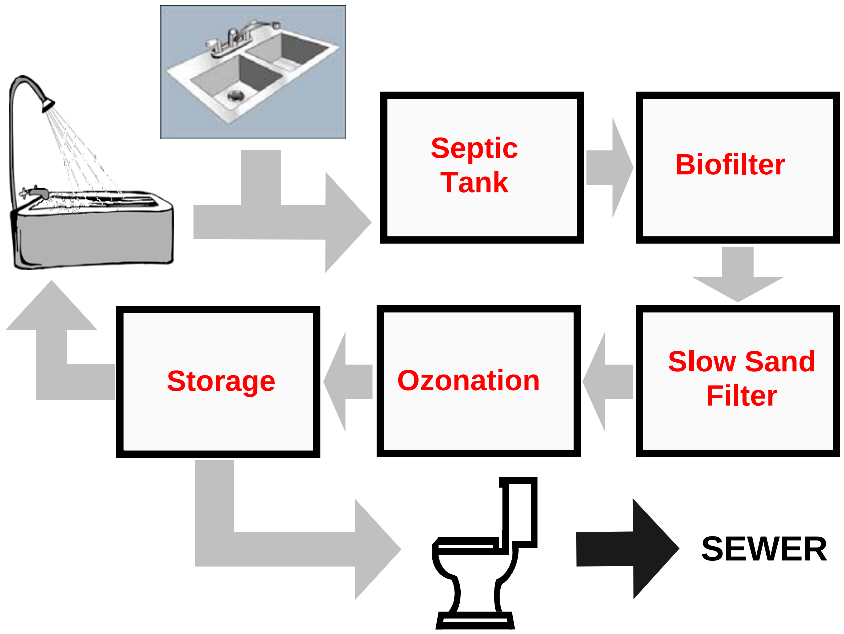

Figure 9 Quayside Village Water Reuse Treatment System

Cost:

The capital cost of the equipment was approximately $115,000, or $5,750 per unit.

4.7 Conservation Coop, Ottawa, Ontario

Conservation Co-op is a four (4) story eighty-four (84) unit apartment building, located in the Sandy Hill district of the City of Ottawa, whose tenants are committed to provide "green" alternatives in an environmentally friendly building reducing the consumption of energy, water and waste to levels significantly lower than those of conventional households. Constructed in 1995, the project incorporates water conserving plumbing fixtures that resulted in a normalized water use per apartment of 390 L/day compared to a typical apartment water consumption of 530 L/day in the Ottawa area.

The Research Division of CMHC arranged to have the bathrooms in eight of the 84 apartments constructed with dual plumbing systems. One plumbing system allowed the bathrooms to operate normally using municipal water and sewage piping. The other parallel plumbing system connected the drains from the bathtubs to a light greywater treatment system. This system receives water from the bathtubs, treats it and then reuses the treated effluent for use in the toilets of the eight apartments.

Discussions were held with the Ministry and City officials to develop treatment criteria. The criterion for the design of the treatment system, outlined in Table 5, were established and accepted by the Regional Health Department on the understanding that this was an experimental system for water reuse; strictly for toilet flushing. Note that no consideration was given to the biochemical oxygen demand of the greywater.

Table 5 Water quality objectives for Conservation Coop greywater reuse system

Parameter	Treatment Objectives
Total Suspended Solids (mg/L)	30
Escherichia Coliform (CFU/100 mL)	0
Turbidity (NTU)	20
Colour (TCU)	20
Iron (mg/L)	1
Manganese (mg/L)	0.5

The average daily water use was 640 L/day for toilet flushing, 1,300 L for bath/shower water and 700 L/day for other uses (there are no laundry facilities in individual apartments).

A literature review of greywater treatment technologies was used to select two treatment options for a pilot-scale testing program: 1) slow sand filter; and 2) rapid sand filter. The pilot-scale study was not as successful as anticipated; however, the project proceeded with a greywater treatment process design based on a sand pressure-filter system.

Treatment Process Description

The greywater treatment system was completed and commissioned for use in August of 1999. It consisted of the following components (Figure 10):

1. Basket screens (1 mm mesh) to trap hair, lint and other large particles. Sodium hypochlorite pucks placed in the screening baskets to control odours and filter biofouling.

2. Equalization (440 L) tanks to remove floatable oils, scum and settleable solids, as well as provide initial disinfection. Accumulated solids and scum are automatically discharged to sewer after each fill-draw cycle is complete.

3. Pump to transfer liquid from the equalization tanks through a multi-media pressure filter.

4. Upflow multi-media pressure automatic-backwash filter to remove particulate material. These types of filters are more commonly used in potable water treatment systems and do not remove BOD.

5. Ozone that is added to the filtered water prior to discharge into a treated water tank.

6. Storage tank (600 L).

7. Distribution pump that is activated by a drop in pressure (toilet flushing) within the distribution system.

Process Performance

By late September 1999 the filter media had to be replaced, and by mid-October one of the system pumps had failed and the system was down for two weeks until the pump could be replaced. A valve and pump failure in November shut the system down until early December 1999. In March 2000, the treatment system was shut down and the toilets to the eight units were once again connected to water from the city supply. This action was taken in response to extensive complaints from the residents of the eight apartment units regarding problems with odour and rapid scum accumulation in the toilets, and an incident in which ozone release from the treatment facility caused injury to the maintenance supervisor.

An independent review of the treatment system noted the greywater had a significant biochemical oxygen demand (BOD_5) of 130 mg/L that had not been taken into consideration in the treatment process design. No biological treatment had been provided for. As a consequence, the filtered greywater rapidly became anaerobic, producing the black foul-smelling water that was being reused for flushing the toilets. Further, the toilets for the eight apartments were subjected to significant water-hammer effects as a result of the transfer pump and temporary nature of the pilot installation, resulting in loud banging noises and vibrations that were extremely disconcerting to the residents. The flow and pressure specifications of the pump was inadequate to meet the demands of more than one toilet flushing simultaneously, requiring the residents to flush their toilets repeatedly.

The following remedial measures were recommended to improve system performance and address the problems observed with the Conservation Co-op reuse water treatment system:

- Add a biological treatment component to reduce the BOD concentration to less than 10 mg/L.
- Add a pressure tank to the distribution system to improve water supply to the toilets.
- Remove the ozone system and replace it with either a secondary chlorination or ultraviolet disinfection system.

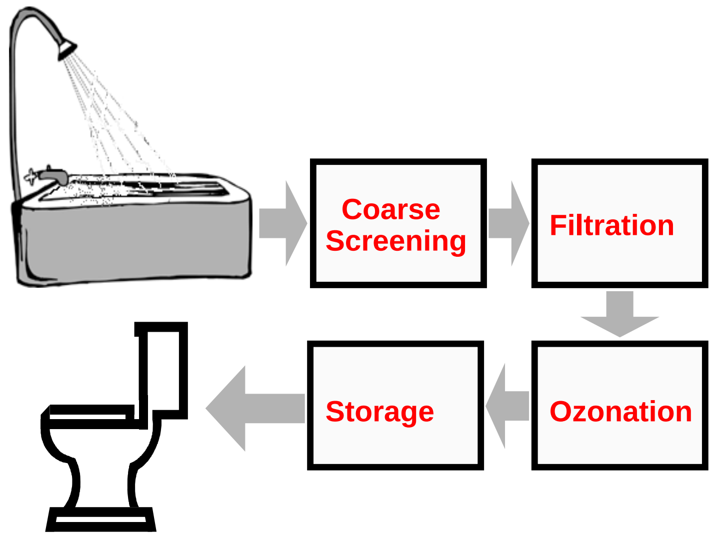

Figure 10 Conservation Co-op Greywater Treatment System

Lessons Learned

The CMHC Conservation Co-op pilot project demonstrated that residential greywater reuse can save water and reduce the sewage and water demands on municipal systems. The project also demonstrated that significant operating and maintenance problems can be experienced with greywater reuse systems if wastewater characterization is not considered in the design, and appropriate components are not incorporated in the treatment system to remove BOD. Greywater must be treated if it is to be stored for any significant period of time, or if it is to be distributed through plumbing for any indoor application.

Cost

The system cost, (excluding pilot testing but including design, materials, installation, and commissioning, was reported to be $30,000, or $3,750 per unit,

4.8 Toronto Healthy House, Toronto, Ontario

Project Background

The Toronto Healthy House project was a result of a Canada-wide "Healthy Housing Design Competition" held by CMHC. The two side-by-side residences have no connection to the municipal water or sewage infrastructure, and are situated on small inner city lots (6 metres by 22 metres). The dwellings rely on rainwater harvesting for potable water, and reuse water for all other domestic water needs (i.e. toilet flushing, laundry, bath/showers, and irrigation).

Water Reuse Treatment Process Descriptions

Both blackwater and greywater are collected and treated for reuse as illustrated in Figure 11. The treatment process consists of the following components:

1. A 3000 L septic tank, which has been divided into two unequal (2/3-1/3) compartments. The first compartment is intended to remove coarse solids and grease, and the second is equipped with hanging filter cloths intended to remove colloidal solids.
2. Biofilter (Waterloo™) with recirculation back to the septic tank inlet.
3. Roughing filter to remove coarse biosolids.
4. Slow sand filter to remove fine particles (both the roughing and slow-sand filters are automatically back-washed).
5. In-line ozone injection using a venture-style aspirator, followed by a contact tank.
6. Storage tank

The stored reuse water is used for toilet flushing, garden irrigation, laundry, and bathing/showering purposes. Any wastewater that is in excess of the reuse requirements of the household is discharged to a gravel bed in the front yard. The treated reuse water is not subjected to further disinfection methods (e.g. chlorination) following ozone disinfection.

A three-component filter (roughing filter, slow sand filter and activated carbon filter) was originally installed but has since been decommissioned and replaced with the separate roughing filter and slow sand filter due to problems experienced with filter clogging.

<u>Process Performance</u>

Online turbidity, flow, and water quality data for both the potable and reuse systems has been collected by an independent agency since November 2000.

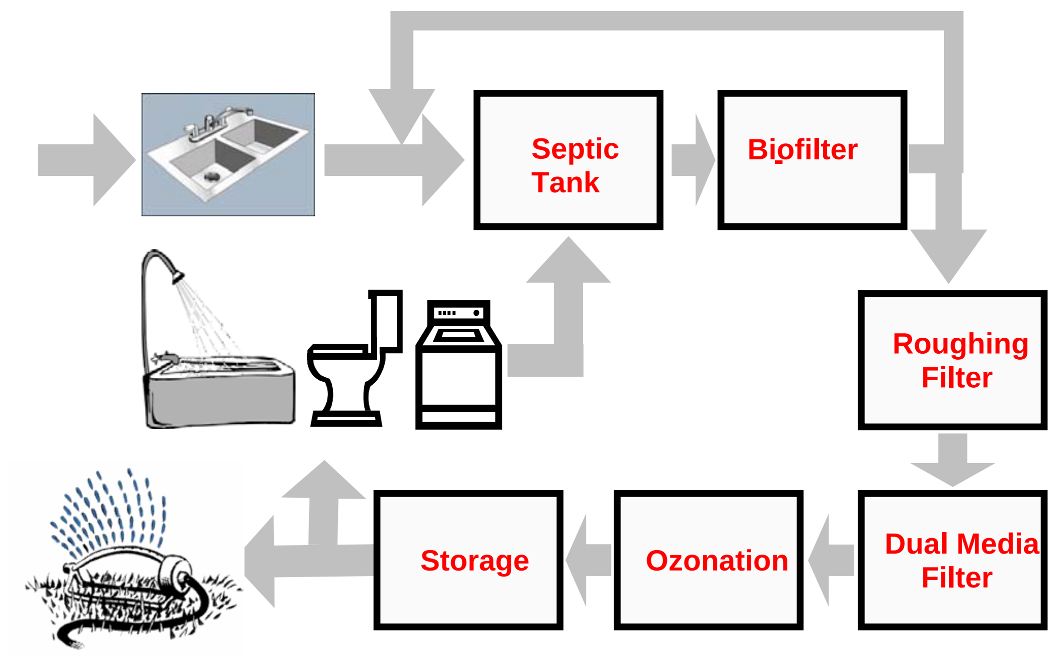

Figure 11 Toronto Healthy House Water Reuse Treatment System

Water quality objectives for the reuse water systems are illustrated in Table 6. Analytical parameters monitored include: 1) Bacteriological (total coliforms, E. coli and background bacteria); and 2) Chemical for reuse (pH, nitrite/nitrate, BOD, TSS, TDS, sodium, chlorides, phosphate, and ammonia).

Table 6 Reuse Water Quality Objectives for Toronto Healthy House

Parameter	Treatment Objectives
BOD (mg/L)	$\leq$ 10
TSS (mg/L)	$\leq$ 10
Total Coliform (c/100 mL)	< 1
E. coli (c/100 mL)	< 1
Turbidity (NTU)	$\leq$ 2

Although the reuse water quality BOD, TSS, and turbidity criteria have been consistently met, the total coliform bacteria criteria have not been met at times, and heterotrophic plate counts are elevated, indicating bacterial regrowth in the reuse storage tank and distribution system. Regrowth can include "opportunistic pathogens" such as strains of *Psuedomonas aeruginosa*, *Acinetobacter spp.*, *Aeromonas spp*., etc. The potential for regrowth is of particular concern where the water is being sprayed and potentially inhaled, as in the case of using potable water or reuse water for showers. Strains of *Klebsiella pneumoniae*, and *Legionella pneumophila* if inhaled as aerosols can cause severe illness. Water temperatures of 30 to 50 ^{o}C are favorable to the growth of *Legionella*.

Another concern with the existing treatment system was that ozone was being released into the residence, and may pose a health hazard to the occupants.

Changes to Improve Performance

As a result of the independent process review, the following remedial measures were recommended to improve system performance and address the problems observed with the Toronto Healthy House reuse water treatment system:

- An ozone sensor and alarm should be installed, and consideration given to modifying the ventilation of the equipment space to ensure the ozone is destroyed and the gas is ventilated outside of the structure.

- Either a secondary chlorination or ultraviolet disinfection should be added to both the potable and reuse water treatment systems to inhibit bacterial regrowth within the storage and distribution systems. The Provincial health agency would prefer to have a minimum 1 mg/L chlorine residual maintained within the distribution system.

Lessons Learned

The CMHC Toronto Healthy House residential project demonstrates reuse water treatment can be done within a family residential dwelling setting, with reuse applications including toilet flushing, bathing/showers, laundry and irrigation. Although the project was designed to treat mixed wastewater (greywater and blackwater) instead of only greywater, it does demonstrate that a high level of reuse water quality in terms of BOD, TSS and turbidity can be consistently met treating either greywater or blackwater. Bacterial water quality objectives have not been reliably met, however, suggesting alternative disinfection methods are needed.

Careful consideration must be given to ensure that ozone used in a residential application is properly ventilated, and that consideration is given to controlling regrowth of bacteria within the storage and distribution systems. One method of achieving this is to maintain an adequate residual chlorine level within the treated water storage tank.

4.9 Go-Green Wastewater Systems

As described in Section 3.4.1, Go-Green[6] is a B.C. manufacturer of small advanced wastewater treatment systems. The treatment process consists of: 1) a septic tank, 2) fermentation cell containing fixed media, 3) aerated moving bed bioreactor (fixed media) cells, and 4) settling tank. UV disinfection can be added, if necessary.

Staring in mid 2004, Go-Green installed four of its units aboard floating structures. These include a floating fishing resort (Photo 6), a float home (Photo 8), a converted live-on-board fishing vessel (Photo 7), and a floating Federal Fisheries camp (Photo 9). Details of these installations are presented in Table 9. In all cases, the wastewater treated is a combination of black water and greywater. The tankage of the treatment unit has been modified to fit within the tight space normally associated with these floating marine installations (see pictures).

Generally, these treatment systems installed aboard the floating structures and vessels have been designed to comply with Section 99 of the proposed Prevention of Pollution From Vessels Regulation under the Canada Shipping Act 2001 (CSA 2001) and meet the following effluent quality:

- A fecal coliform count of under 250 coliforms/100ml M.P.N.
- Total suspended solids content of under 50 mg/L
- Biochemical Oxygen Demand (B.O.D.$_5$) of under 50 mg/L
- Total residual chlorine of under 0.02 mg/L

For the Macmell Federal Fisheries camp (Photo 9), due to space limitations, the treatment unit (2.1 x 2.4 m) was installed inside its own 3.5 x 7 m float and attached to the side of the camp building.

Land-based Go-Green units achieve BOD and TSS levels of under 10 mg/L with fecal coliform levels of under 400 counts/100 ml without resorting to disinfection. The data on marine-floating

[6] Go-Green Sewage and Waste Water Treatment Systems Ltd.

home installations is more limited since the installations are very recent. The results of one treated effluent sample analyzed for a float home in Delta about a month after installation is presented in Table 9.

Table 7: Summary of Go-Green Installation in Float Homes and Live-on-Board Vessels

Location	Date of Installation	Type of Float Home	Design Flow (m^3/d)	Comments
Naden Harbour, Queen Charlotte Islands	May 2004	Floating hotel - Samson fishing lodge resort	1.8	4 systems, two to treat up to 9 staff and two for up to 18 guests each.
Converted fishing vessel	August 2004	Live on board and weekend charter	0.9	Designed for a crew of 2 and up to 6 passengers (20 gpd).
Delta	January 2005	Residential home (barge) for four people	1.3	26/2/05 treated effluent sample (UV disinfection) BOD 20 TSS 14 FC 2400
Machmell Fisheries Camp	March 2005	Federal Fisheries camp serving up to 6 persons excluding kitchen waste	0.5	Low flush toilet and hand sink connected to treatment plant

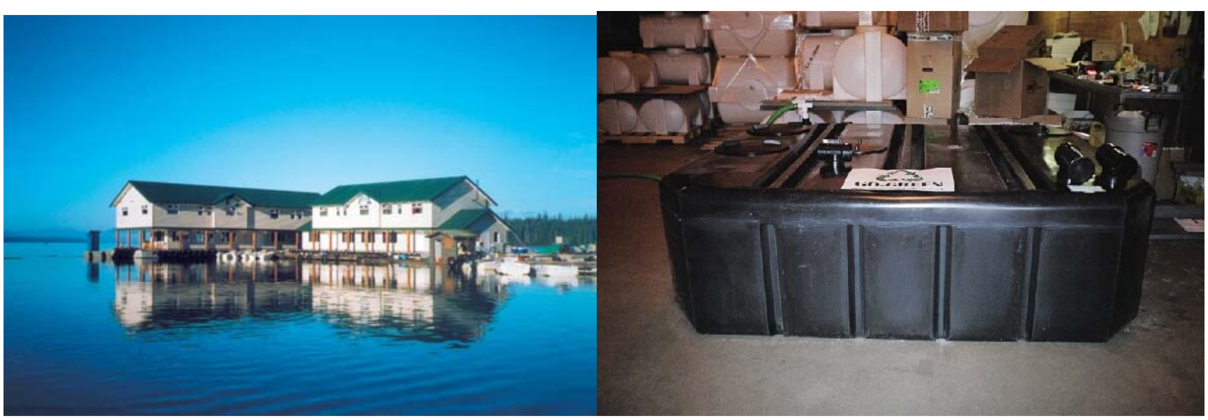

Photo 6 Samson Floating Fishing Lodge in Queen Charlotte Islands and a customized 3 compartment treatment tank with reduced height to fit underneath floor

Photo 7 Ocean Viking converted fishing vessel and Go-Green treatment system aboard

Photo 8 Delta float home and Go-Green treatment system

Photo 9 Aerial view of Machmell Federal Fisheries camp and of Go-Green treatment system inside its own float prior to shipping (flexible piping connection shown will be used to connect to float camp plumbing).

5 BC REGULATIONS AFFECTING GREYWATER REUSE

British Columbia has two primary regulations, under two separate Acts, that deal with residential wastewater issues, but only one has provision for water reuse system, specifically (the new Sewage System Regulation does have provision for shallow sub-surface applications - although not specifically in reference to reuse water).

5.1 Health Act – Sewerage System Regulation

The Health Act Sewerage System Regulation (B.C. Reg. 326/2004 - O.C. 701/2004), which will be effective on May 31, 2005, addresses treatment and disposal criteria for sewage originating from single family dwellings to subdivisions with flows less than 22,700 litres per day discharging to ground. The Regulation is silent on the issue of greywater systems or water reuse, but does define "the discharge of domestic sewage or effluent onto land" as a "health hazard" unless "authorized under another enactment" {Section 3(2)}. The Regulation also defines "sewage" as being both greywater and blackwater combined).

The Sewerage System Regulation does not address the practice of water reuse, or more specifically greywater reuse within a residence and the Ministry's perspective (J. Rowse, person. communication) is that greywater or mixed-wastewater reuse applications within a single family residence would not be of concern to the Ministry. However, greywater reuse systems that would affect a number of residences (e.g. Quayside Village) would be of concern to the Ministry.

5.2 British Columbia Building Code – Non-Potable Water Systems

The Canada Mortgage and Housing report titled "Regulatory Barriers to Onsite Water Reuse" notes that while the "National Plumbing Code provides for alternative systems such as dual water distribution within sites" it also "prohibits the discharge of non-potable water through outlets such as faucets or toilets".

The BC Building Code also provides for non-potable water systems, and restricts outlets where they can discharge into "a sink or lavatory" (toilet).

5.3 Waste Management Act – Municipal Sewage Regulation (MSR)

The only regulation in BC that addresses the issue of reclaimed water, and inherently greywater reuse, is the Waste Management Act - Municipal Sewage Regulation (MSR). The MSR describes the conditions to permit reclaimed water to be used for a range of application. The conditions include a minimum effluent quality criteria, the completion of an environmental impact assessment and operations plan, treatment system component redundancy, and the posting of financial security for operations and a capital replacement fund.

The MSR reclaimed water requirements apply only to discharges from two or more dwellings, and domestic sewage or treated effluent discharges originating from a single residence or dwelling is exempt from the provisions of the MSR.

Table 13 illustrates the effluent quality requirements as they are related to reclaimed water applications for treated wastewater. Parameters of concern are pH, BOD, TSS, turbidity and fecal coliform.

Table 8 BC Waste Management Act – Municipal Sewage Regulation – Reclaimed Water Criteria

Class	Reuse Application	Effluent Quality Requirements				
		Median FC (CFU/100ml)	**BOD (mg/L)**	**TSS (mg/L)**	**pH (90%)**	**Turbidity (NTU)**
Unrestricted public access	**Urban:** Parks, playgrounds, cemeteries, golf courses, road right of ways, school grounds, residential lawns, green belts, vehicle and driveway washing, landscaping, toilet flushing, outside fire protection, street cleaning **Agricultural:** Aquaculture, food crops eaten raw, orchards and vineyards, pasture, frost protection, seed crops **Recreational:** Stream augmentation, impoundments for boating and fishing, snow making	≤ 2.2	<10	≤ 5	6-9	≤ 2
Restricted Public Access	• Urban/Recreational: • Landscape Impoundments • Landscape Waterfalls • Snow Making (not for skiing and snowboarding)	≤ 200	≤ 45	≤ 45	6-9	-
	Monitoring Requirements (unrestricted access)	daily (1)	weekly	daily	weekly	continuous

British Columbia Ministry of Environment, Lands and Parks. (1999). "*Regulation 129/99. Waste Management Act Municipal Sewage Regulation*."

5.4 Discussion

Wastewater systems and, by association, greywater reuse systems, for a single residence or dwelling are exempted from the Waste Management Act.

Greywater reuse for surface irrigation for a single residence is not permissible under the Health Act as it is defined as a "health hazard" under section 3(2) of the Sewerage System Regulation.

Greywater reuse for toilet flushing in general is not permissible under the plumbing code which states than "an outlet from a non-potable water system shall not be located where it can discharge into … a) a sink or lavatory".

Consequently, the only greywater application that appears to be permissible for a single family residence in British Columbia is where the discharge is to ground and where such a discharge complies with the requirements of the Health Act - Sewerage System Regulation (i.e. the new Sewage System Regulation does have provision for shallow sub-surface irrigation applications).

Greywater reuse is permissible for two or more dwellings implementing a collective greywater reuse system, as long as the system complies with requirements specified under the Waste Management Act Municipal Sewage Regulation including: the completion of an environmental impact assessment and operations plan, effluent quality criteria, system component redundancy, and the posting of financial security for capital and operating costs or registration under an approved assurance plan (for private systems).

A further regulatory complication for using greywater for flushing toilets within a single-family dwelling or multi-family complex, is the National Plumbing Code, which “prohibits the discharge of non-potable water through outlets such as faucets or toilets”. However, there are several examples in Canada and BC (see Quayside Village Case Study) where toilet applications have been permitted.

6 ECONOMICS

6.1 Costs

The two key capital cost components for greywater systems are for treatment and dual plumbing. The costs of treatment for a new single residential source would be expected to range from $750 for the supply and installation of a simple diversion device to about $10,000 for the supply and installation of a biological treatment system (regardless of the technology selected), plus the cost of providing a dual plumbing system for the reuse water.

Discussions with the manufacturer of the Go-Green system indicated that the costs of the technology for floating home applications ranges from $8,000 to $15,000 for the supply of the components & tanks, to a total of $25,000 for a completely equipped floating tender unit.

6.2 Australian Greywater System Cost Experience

Table 9 illustrates system materials, costs, and energy & maintenance requirements for a range of greywater reuse approaches based on experience in Australia. The amounts shown in the table are in Australian dollars, which is fairly close to Canadian currency at the time of writing. The reductions in water consumption resulting observed in Australian case studies is illustrated in Table 10.

Table 9 Greywater system materials, costs, energy and maintenance requirements {AUS $} (from Australian Water Association CSIRO, April 2004)

Process type	*Lo or Hi tech*	*Materials/major components*	*Capital cost per household*	*Energy usage*	*Operation and maintenance requirement*
Simple diverter valve	Low	uPVC pipe	$30-40	None - Gravity fed for irrigation	Minimal maintenance of valve. Continuous user control of irrigation area
Sedimentation tank and ecosoil irrigation field	Low	Standard piping Tank Gravel/ecosoil	$12000 (1000 L/day)	Gravity fed or pumped	Continuous user control of irrigation Desludging of sedimentation tank
Diverter valve, filtration, storage (drip irrigation)	Low	Piping Tank Pump Drip piping	$30-40 $250 $250 $1-2/m	Pumping required	Continuous user control of irrigation Filter cleaning
Sand filter[1] (for subsurface irrigation or toilet flushing)	Low	Tank Pump UV lamp	$5500	Pumping and UV 7.2 kWh/kL (80% for UV)[1]	Continuous user control of irrigation None specified UV lamp replacement?
Aeration (for toilet, garden and clothes)	High	Coarse filtration Tank Pumps Air blower UV lamp Microprocessor	$6500	Air blower Pumping UV Total 0.6 kWh/day (for 2400 L)	UV lamp replacement (annually)
Electroflotation (for toilet, garden and clothes)	High	Tank Pumps x2 Electrodes pH control Microprocessor	$7500	0.5-0.8 kWh/kL	Electrode replacement
Pressure filtration (toilet, garden and clothes)	High	Coarse filtration Tanks Pumps Filtration medium UV lamp Microprocessor	NA	Pumping required	Coarse filter cleaning (monthly) Replace filter media (annually) Desludge tank (annually) UV lamp replacement (annually)

1 Gardner et al., 2003

Table 10 Greywater system water savings (from Australian Water Association CSIRO, April 2004)

Reference	*Location*	*End use*	*% potable water reduction*
Gardner *et al*., 2003	Gold Coast, Queensland	Potential toilet flushing and irrigation but discharged to sewer[1]	36%[2]
WAWA, 1993	Western Australia	Garden irrigation with 'water wise' gardening	38%[2]
Priest *et al*., 2003	Perth, Western Australia	Irrigation	4500 to 40,500 ML/year[3]
Christova Boal *et al*., 1996	Melbourne, Victoria	Garden irrigation Toilet Toilet and garden	21%[2] 20%[2] 31%[2]
Diaper *et al*., 2003	Canberra, ACT	Garden irrigation	13% to 22%[2]

1 Queensland Sewage and Water Supply Act (1949) does not allow reuse
2 Potential saving
3 Potential saving for 100% utilisation and range of uptake

7 SUMMARY

The following provides a brief summary of the information presented in this document pertaining greywater treatment and reuse for floating home applications.

- Greywater is domestic wastewater excluding discharges from toilets and urinals. It can be sub-divided into two categories based on the level of contaminants present: 1) light-greywater; and 2) dark greywater. Light-greywater typically originates from bathroom tubs, showers, and sinks, in addition to laundry wash-water. Dark-greywater usually refers to kitchen sink drainage that often contains substantial quantities of organic materials and grease & oil.

- Regardless of the source, domestic greywater contains the same contaminants as blackwater discharges from toilets and urinals including soluble and particulate organic material, and pathogenic micro-organisms, although the level of contamination (concentration) is expected to vary depending on the source. The organic contaminants must be biologically treated and removed if the greywater is to be stored for any significant period of time, and the technologies used to treat greywater and blackwater sources are the same, typically incorporating some form of aerobic biological treatment and disinfection unit processes.

- The Waste Management Act Municipal Sewage Regulation (MSR) has provisions for reclaimed water reuse, which includes greywater systems. With respect to reclaimed water use, the MSR applies only to sewage or reuse water applications for clusters of two or more dwellings. The MSR includes specific requirements for environmental impact assessment, operations plans, security (100% capital replacement & operations security funds) and technology (system redundancy and chemical flocculation & filtration) and operations specifications (operator certification, sampling, monitoring & reporting) that may be onerous for small private systems and make greywater reuse impractical. Furthermore, all reclaimed water systems must also have the written approval from the Ministry of Health.

- With respect to individual residential (onsite) applications, the current regulatory environment in British Columbia is a barrier for greywater reuse. Because individual dwellings are exempt from the MSR, they fall under the jurisdiction of the Ministry of Health through the Sewerage System Regulation, and discharges from individual residences must conform to the ground disposal requirements of the Regulation (the Regulation does not specifically address the issue of greywater or water reuse). Although greywater reuse applications within a single residence would not typically be of concern to the Ministry of Health, the restrictions within the B.C. Building Code for Non-Potable Water Systems prohibit the location of an outlet for a non-potable water system where it can discharge into “a sink or lavatory” (toilet).

- Potential on-board treated greywater reuse applications include small garden irrigation, toilet and urinal flushing, bathing & showering, and deck washing. These applications require aerobic biological treatment and disinfection particularly where the treated greywater is to be stored for any significant length of time. Left untreated, stored greywater will quickly become septic and generate noxious odours. Furthermore, pathogenic microorganisms in the greywater must be removed through disinfection where there is potential for direct public (human) contact.

- A number of issues need to be taken into consideration when reusing greywater. The system should be as simple and easy to use and maintain as possible. The system also should minimize risks to human health, either by providing for adequate treatment of the greywater, or by minimizing the chance of direct contact with humans.

  The primary components for greywater reuse system intended to generate reuse water for surface irrigation or indoor use with potential for human contact include:

  1. filters to remove hair, lint and coarse solids particles;
  2. sedimentation tanks to separate and remove grease, oils & settleable solids from the greywater;
  3. aerobic biological treatment to remove soluble organic contaminants;
  4. final clarification or filtration to remove solid particles and bacteria generated during biological treatment;
  5. disinfection to remove pathogenic (disease causing) micro-organisms;
  6. reuse water storage tank.

- While many direct diversion greywater systems provide some form of filtration, full biological treatment is needed if the greywater is to be stored for any significant period of time or is likely to come into direct contact with humans. However, if greywater is to be used for subsurface irrigation or is to be used for other applications where it is unlikely to come in contact with humans (i.e. toilet or urinal flushing), and does not require extended storage - then coarse filtering to remove hair & debris or conventional septic tank treatment to remove grease/oil/scum/settleable-solids may be adequate treatment.

  The types of technologies required to aerobically biologically treat greywater are identical to those used for domestic wastewater treatment, and may be based on either suspended growth (e.g. activated sludge) or fixed film (e.g. RBC) aerobic biological treatment technologies.

- Greywater diversion and filtration systems applied to direct-use subsurface irrigation applications are relatively simple in concept and to operate and maintain.

- One BC Company "Go-Green" was identified as marketing a wastewater treatment system for treating both black and grey-water for on-board floating home applications in British Columbia. A brief literature review was unable to identify any other onboard greywater treatment or reuse applications.

- All greywater systems require plumbing skills to install, and depending on the type of treatment may require an electrical contractor as well. Filtration systems used in direct diversion subsurface irrigation applications can generally be serviced by a homeowner, and typically involves periodically cleaning a filter screen. More complex aerobic biological treatment systems typically require plumbing and electrical skill sets, as well as some basic knowledge of biological treatment typically covered in an operator-training program. Often this maintenance is contracted to the equipment supplier with scheduled inspection/maintenance intervals of once every six months. Regardless of complexity, all systems should have written operating instructions that detail operations and maintenance information, in addition to providing specifications on all mechanical and electrical equipment components.

- Capital cost for residential greywater systems ranges from $750 for the supply and installation of a simple diversion device to up to $15,000 for the supply and installation of a biological treatment system (regardless of the technology selected). The single system (Go-Green) identified in use in floating home applications costs from $8,000 (supply of internal components and equipment only) to $15,000 (complete with tanks), which appears to be similar in cost to the residential applications.

- Little data was found on wastewater characteristics (volume, contaminants, temperature range etc.), physical constraints (i.e. typical plumbing configuratons, power availability, onboard water use characteristics etc.), site constraints, and other parameters relating to the selection of appropriate technologies for typical floating home application. Additional work is recommended.

BIBLIOGRAPHY

Australian Water Association & CSIRO. 2004. Innovation in on-site domestic water management systems in Australia: A review of rainwater, greywater, stormwater and wastewater utilization techniques. CSIRO MIT Technical Report 2004-073. April 2004.

Booker, N. (1999) Estimating the economies of scale of greywater reuse systems, Program report FE-88, CSIRO Molecular Science.

Brennen, M. and R. Patterson. 2004. Economic analysis of greywater recycling.

British Columbia Ministry of Environment, Lands and Parks. (1999). "*Regulation 129/99. Waste Management Act Municipal Sewage Regulation.*" Victoria, British Columbia http://www.qp.gov.bc.ca/statreg/reg/W/WasteMgmt/129_99.htm

British Columbia Ministry of Health (2004). "Regulation 326/2004. Health Act: Sewerage System Regulation". Victoria, British Columbia http://www.qp.gov.bc.ca/statreg/reg/H/Health/326_2004.htm

British Columbia Ministry of Health (1985). "Regulation 411/. Health Act: Sewage Disposal Regulation". Victoria, British Columbia http://www.qp.gov.bc.ca/statreg/reg/H/Health/411_85.htm

Canada Mortgage and Housing Corporation. 1998. "Regulatory Barriers to On-site Water Reuse" Technical Series 98-101.

CSIRO. 2004. The Economics of Water: Taking Full Account of First Use, Reuse and Return to the Environment. Folio No. S/031474. March 2004.

Diaper, Clare., April 2004. Innovation in on-site domestic water management systems in Australia: A review of rainwater, greywater, stormwater and wastewater utilisation techniques. CSIRO MIT Technical Report 2004-073. 31pp.

Dillon, Peter. 2000. Water Reuse in Australia: Current Status, Projections, and Research. Water Recycling Australia 2000. Adelaide, 19-20 Oct 2000. pp. 99-104.

Dyck, E. "*Greywater*", **Onsite Sewage Disposal**, No. 9, Spring 2001

Gaines, F., and M. Zavoda. 2004. "*Reuse of treated wastewater*", NOWRA Water Reclamation, Recycling and Reuse Seminar, Nov. 2004.

Gruvberger, C. et al. "*Sustainability concept for a newly built urban area in Malmö Sweden*", **Water Science and Technology**, Vol. 47, No. 7-8, 33-39. IWA Publishing, 2003.

Gray, S. and Bookner, N. "*Wastewater Services for Small Communities*". **Water Science and Technology**, Vol 47, No. 7-8, 33-39. IWA Publishing, 2003.

Gartner, T. QLD Dept of Natural Resources, "*Water Case Studies - Healthy Home*" **Australian Greenhouse Office**, Queensland Australia, 2004
http://www.greenhouse.gov.au/yourhome/technical/fs26.htm

GWA. 2003. *A Mandatory Water Efficiency Labelling Scheme for Australia.* Final report prepared for Environment Australia by George Wilkenfeld & Associates. Sydney.

Kambanellas, PhD, C.A. "*Recycling grey water in Cyprus*", **6th specialist Conference on Small Water & Wastewater Systems & 1st International conference on Onsite Waste Water Treatment & Recycling**, 11-13 February 2004, Western Australia.
Lopez Zavala, M.A. Funamizu, N. Tatakuwa, T. "*Onsite wastewater differential system: modeling approach*". **Water Science and Technology**, Vol. 46, No. 6-7, 317-324. IWA Publishing 2002.

Mars, R. "Case Studies of Greywater Recycling in Western Australia" ", **6th specialist Conference on Small Water & Wastewater Systems & 1st International conference on Onsite Waste Water Treatment & Recycling**, 11-13 February 2004, Western Australia.

Media Release: Judge, C. "*Recycled water for 10,000 new homes*", 09 August 2004, http://www.sydneywater.com.au/WhoWeAre/MediaCentre/MediaView.cfm?ID=235

Media Release: Minister of Water, Minister of Environment, Victoria, Australia "*NEW TOWN TO BE FULLY CONNECTED TO RECYCLED WATER*", August 13th 2004-water-recycling@lists.dnr.qld.gov.au

Nolde, E. "*Greywater Recycling Systems in Germany – Results and Guidelines*", **6th specialist Conference on Small Water & Wastewater Systems & 1st International conference on Onsite Waste Water Treatment & Recycling**, 11-13 February 2004, Western Australia.

National Resources Defense Council and the Pacific Institute. 2004. Energy Down the Drain – The Hidden Costs of California's Water Supply. August 2004. 79 pp.

Ottosoin, J. and Stenström, T.A. "*Faecal contamination and associated microbial risks*". **Water Research**, Vol. 37 (2003) 645 – 655. IWA Publishing 2003.

PriceWaterhouseCoopers. 2000. Economic Aspects of Water Recycling in Queensland.. April 2000.

Queensland Government Environmental Protection Agency. 2001. Recent Advances in Water Recycling Technologies. A.I. Schäfer, T.D. Waite, P.Sherman (Eds.)

Surendran, S. "*Performance of on-sight Greywater Reclamation Systems.*" , **6th specialist Conference on Small Water & Wastewater Systems & 1st International conference on Onsite Waste Water Treatment & Recycling**, 11-13 February 2004, Western Australia.

West, S. M. 2003. *On-site and Decentralised Sewage Treatment Reuse and Management Systems in Northern Europe & the USA - Report of a study tour - February to November 2000*. 104pp.

GREYWATER TREATMENT TECHNOLOGY WEBSITES

http://www.ecologicalhomes.com.au/wastewater_systems.htm
http://www.electropure.com.au/products/pro3_dbk200.html
http://www.clivusmultrum.com/greywater.html
http://www.envirosink.com/about.html
http://www.greywatersaver.com/contact.htm
http://www.aquaclarus.com/prod_sim_how.htm
http://www.nature-loo.com.au/greywater/natureclear/natureclear.html
http://www.biolytix.com/filtration
http://www.copa.co.uk/products/mbr/default.asp
http://www.greywater.com/e_s2_konzept.html
http://www.electropure.com.au/techinfo/index.html