THESIS

REGULATORY ISSUES ASSOCIATED WITH GRAYWATER REUSE

Submitted by

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ABSTRACT

REGULATORY ISSUES ASSOCIATED WITH GRAYWATER REUSE

Concerns over limited water resources in arid and semi-arid regions in addition to overloaded and/or costly wastewater treatment facilities have resulted in utilities looking toward new concepts for water management. This is particularly true in the Southwestern United States. One approach which is increasingly gaining popularity is the reuse of graywater for nonpotable applications. Graywater reuse has been known to be prevalent in the U.S. for at least 10 years. A study conducted by the Water Conservation Alliance of Southern Arizona showed that 13% of homes were reusing graywater in the year 2000. Despite the prevalence of graywater reuse, most current regulations have not been based on science and states currently looking toward developing regulations and guidelines on the safe reuse of graywater are seeking guidance on doing so. Also, the link between graywater constituents and risk to human health has not been well studied. Therefore, the risks posed to human health by graywater reuse remain largely unknown.

The objective of this project is to gather useful data on the water quality, currently available technologies and standards for integrating graywater systems into various types of localized sites. Additionally, surveys from state health officials (including states that allow graywater use and states that lack a graywater regulation) provide insight on the key issues associated with implementing graywater regulations. The data gathered will help regulatory agencies make decisions based on water quality information, available technologies and

standards. A spreadsheet based end product was created to manage the vast amount of information and sort all the data on water quality, regulations and treatment technologies.

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CHAPTER 1 PROBLEM STATEMENT

1.1 Introduction

Concerns over limited water resources in arid and semi-arid regions in addition to overloaded and/or costly wastewater treatment facilities have resulted in utilities looking toward new concepts for water management. One method that is gaining popularity is the reuse of graywater for nonpotable applications. In addition to providing substantial water savings, the characteristically low organic content of graywater makes it suitable for nonpotable applications with minimal treatment (Pidou, 2006). In the United States, California, Arizona, New Mexico and Texas have led the graywater movement with regulations already in place and many examples of installed graywater systems. Despite the prevalence of graywater reuse, most current regulations have not been based on sound science and states currently looking toward developing regulations and guidelines on the safe reuse of graywater are seeking guidance on doing so.

The characteristics of graywater quality has been well studied (Eriksson et al., 2002), yet the risks posed to human health by reusing graywater remain largely unknown. Additionally, the risks associated with graywater reuse vary by exposure scenario (toilet flushing versus irrigation) and scale (residential versus commercial) (Dixon et al., 1999). Constituents of concern when the end use of graywater is landscape irrigation include pathogens, viruses and ingredients in personal care products. When toilet flushing is the end use for graywater, the potential exists for human contact with graywater, and thus the primary concern is the presence of pathogens and viruses. Public health officials who aren't familiar with graywater reuse tend to view it as a health risk that must be avoided; those that are more knowledgeable about graywater and the public health risks are divided about its public health threat.

While many states would like to utilize the benefits of reusing graywater, the lack of consistent and credible information on graywater reuse has left health departments and regulatory agencies confused about how to move forward with encouraging graywater reuse. Arizona and California have led the effort in enabling graywater reuse. However, these states have adopted vastly different approaches to permitting and regulating graywater reuse systems. For example, Arizona allows graywater reuse without a permit for systems with a capacity less than 400 gallons per day, yet California requires a permit for all graywater systems, excluding washing machine applications. Additionally, California has implemented more strict requirements for system installation. The discrepancy in the approaches taken by these states has left other states confused about which regulation to adopt. In addition, differences in risks depending on the end use (i.e. drip irrigation versus toilet flushing) or whether a system is at the household, apartment, or neighborhood scale adds to the complexity of developing standards for graywater reuse. One of the goals of this project is provide guidance on addressing regulatory differences and identify the underlying issues associated with developing graywater regulations based on a survey conducted to states from all regions of the United States.

While graywater can be used for a wide variety of non-potable and potable applications, the more treatment required, the more a system costs and the more regulatory requirements are encountered. It is plausible to treat graywater to potable quality, yet due to current regulatory restriction and cost of treatment, it is an uncommon application. An alternative use of graywater is to provide enough treatment for non-potable applications such as toilet flushing, irrigation, window wash, car washings, groundwater discharge or fire extinguishing (Abu Ghunmi et al., 2010). For residential purposes, the amount of graywater generated can meet demands for toilet flushing and partial outdoor irrigation demands. Therefore, the four applications of graywater examined in this report are:

- Individual household graywater reuse for irrigation
- Individual household graywater reuse for toilet flushing
- Multifamily/commercial graywater reuse for irrigation
- Multifamily/commercial graywater reuse for toilet flushing

1.2 Organization of Thesis

The author would like to acknowledge the data and information collected for this project is fully documented in “Treatment, Public Health, and Regulatory Issues Associated with Graywater Reuse,” Project 10-02 through the WateReuse Research Foundation. Please reference that report for an in-depth analysis of all data collected. This thesis is a condensed version of the information used to assemble WateReuse Project 10-02. Therefore, there are significant portions of information and findings not discussed in this thesis, especially in terms of treatment for irrigation, treatment for toilet flushing, national regulations, international regulations and an introduction to the graywater tool.

There were two deliverables submitted to the WateReuse Research Foundation required for Project 10-02: a graywater tool and a guidance document. The graywater tool was designed in Microsoft Access compiling the information collected on regulations, surveys and treatment systems into a single database. The main goal of the tool is to mitigate issues in the abundance of information collected into one organized database. All information on state, national and international regulations are available in the database including permit and water quality requirements. Additionally, the database identifies commercially available technologies that meet the water quality requirements based on a regulation of the users choosing. Users can learn more about the type of treatment, maintenance, energy demands and testimonials from system owners for each graywater treatment system. Secondly, the guidance document was constructed to supply information about graywater characterization, public health, environmental issues, regulations and treatment technologies for graywater. The guidance document should be used by regulators interested in adopting graywater regulations to learn more about the subject and how it is regulated.

The layout of this thesis summarizes the information collected for WateReuse Project 10-02. Chapter 2 includes an introduction to graywater quantity, quality, public health issues and environmental issues associated with using graywater for toilet flushing or irrigation. Chapter 3 provides a brief description of the treatment of graywater and available technologies. Chapter 4 is designed to be a rough draft of a journal article based on the bulk findings from the survey and regulations associated with graywater. Therefore, there may be some overlapping information in Chapters 2, 3 and 4. Chapter 5 includes a brief description of the tool and its function. Chapter 6 is a summary and conclusion on the findings found during this research project and gaps in current research for future research needs.

CHAPTER 2 CHARACTERISTICS, PUBLIC HEALTH AND ENVIRONEMENTAL ISSUES ASSOCIATED WITH GRAYWATER REUSE

2.1 Characteristics of Graywater

Graywater (also spelled greywater, grey water, or gray water) is defined as wastewater from lavatory sinks, showers, bathtubs, and laundry machines, and excludes wastewater from dishwashers, kitchen sinks and toilets/urinals. However, the definition of graywater can vary depending on regulatory jurisdictions. Some agencies have elected to include kitchen wastewater in the definition of graywater, yet the most recent graywater literature recommends excluding wastewater from kitchen sinks due to the negative impact on graywater quality (Alkhabtib, 2008). Additionally, some states have defined graywater based on its source. For example, Washington defines light graywater consisting of showers, hand washing basins and washing machines; where dark graywater is defined as all light graywater sources in addition to dishwasher, kitchen waste and utility sink wastes. However, Washington regulates light and dark graywater through different regulations. This same definition has been used by Ramon et al. (2004) to classify two separate definitions of graywater.

The quantity of graywater generated can vary based on available sources, surrounding environment and personal habits. However, as discussed by Gross (2007) multiple sources have accounted for water savings between 50-80% of household wastewater generated. A study conducted by the American Water Works Association analyzed water use data from 14 North American cities consisting of approximately 1,200 households. From this survey, it was estimated that the average total per capita water use is 69 gallons per capita per day (gpcd) as shown in Figure 2.1 (Mayer et al., 1999).

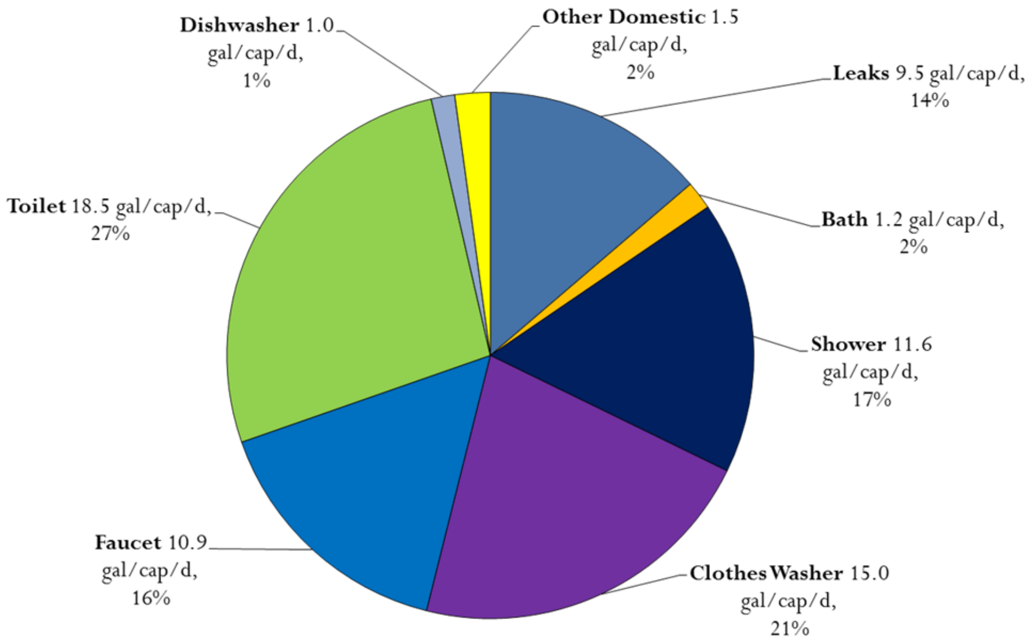

Figure 2.1. Adapted from Residential End Uses of Water by permission. Copyright © 1999 American Water Works Association and American Water Works Association Research Foundation.

The sources of graywater consist of clothes washers (15.0 gpcd), showers (11.6 gpcd), bath water (1.2 gpcd) and a portion of faucet water (10.9 gpcd). Therefore, graywater has the potential to save between 27 – 40 gpcd from a typical residential household in North America. In contrast, and as shown in Table 2.1, North America uses a higher mean quantity of water per capita compared to United Kingdom and Israel. Therefore, water use varies depending on geographic region, potential sources and surrounding environment. Additionally, water use has a tendency to increase with increasing income and decreasing household occupancy (Laine, 2001). This suggests that the amount of graywater produced is dependent on individual homeowners and how they use water.

Understanding the quantity of graywater generated is critical when designing or considering a graywater system. For example, many commercially available graywater systems are designed for a single source of graywater. This means that a system designed to treat laundry water will only save 15 gpcd and get applied only when the appliance is used. An economic analysis of water savings versus system implementation cost should be analyzed prior to constructing a graywater system. Additionally, understanding quantities of graywater generated are required to properly design an irrigation field to ensure soils can safely handle water loads.

Table 2.1. Average Domestic Water Usage

Source of Water	14 United States cities (Gal/cap/d)	United Kingdom (Gal/cap/d)	United Kingdom (Gal/cap/d)	Malta, Israel (Gal/cap/d)	Classification
Bath	1.2	7.4	9.1	6.6	
Shower	11.6				Graywater
Clothes Washer	15.0	4.5	6.8	4.2	
Wash Basin	10.9	3.4	6.7	2.4	Graywater/
Kitchen Sink		3.4	7.8	4.0	Blackwater
Other Domestic	1.6		9.5		Miscellaneous
Leaks	9.5				
Dishwashers	1.0				Blackwater
Toilets	18.5	8.2	16.2	7.7	
Total	**69.3**	**26.9**	**56.1**	**37.5**	

Source: WateReuse Research Foundation project 10-02

2.2 Quality of Graywater

In order to understand the public health and environmental risks associated with graywater, it is first essential to identify the water quality characteristics of graywater. While graywater has been well characterized (Eriksson et al., 2002; Rose et al., 1991l Casanova et al., 2001), the inherent nature and variety of products used in graywater sources is different for each person. As discussed by Al-Jayyousi (2003), graywater is generated by the use of products for washing; its quality varies according to source, geographical location, demographics and level of occupancy. Additionally, the quality and microbial state can change substantially within the course of a couple days of storage (Dixon et al., 1999).

The physical parameters of graywater include temperature, color, turbidity and suspended solids (Eriksson et al., 2002). These particular features are important to the operation of graywater systems. For example, suspended solids from hair and fibers have the potential to clog piping and interfere with the operation of irrigation systems. Additionally, temperature is a feature of graywater that can impact microbial quality. As stated by Eriksson et al. (2002) high temperatures are unfavorable in graywater because they can promote microbial growth.

Chemical characteristics of graywater include the traditional wastewater parameters such as biochemical oxygen demand (BOD), chemical oxygen demand (COD) and nutrients. Nutrients such as nitrogen and phosphorus are of concern for irrigation applications at certain levels due to the benefit to plant growth. Table 2.2 displays the physical and chemical characteristics of graywater. As a comparison, Table 2.2 includes typical untreated wastewater values.

Table 2.2. Average Characteristics of Graywater

	Eriksson et al., 2002			Gross et al., 2007	Metcalf and Eddy, 2003
Parameter	**Bathroom**	**Laundries**	**Kitchen Sinks and Dishwashers**	**Graywater without Kitchen Sources**	**Untreated Domestic Wastewater**
Temperature (C)	29	28-32	27-38		
pH	6.4-8.1	8.1-10	6.3-7.4	6.3-7.0	
Turbidity	28-240	410-1340			
Total Suspended Solids (TSS) mg/l	54-200	120-280	235-2410	85-285	100-350
Total Dissolved Solids (TDS) mg/l	137-1260				250-850
Electrical Conductivity (EC) (µmho/cm)	82-250	190-1400		1000-1300	
Alkalinity	24-67	83-200	20-340		
BOD_5 (mg/l)	76-200	48-380	1040-1460	280-688	110-400
COD (mg/l)	100-424	12.8-725	3.8-1380	702-984	
Total Organic Carbon (TOC) mg/l	30-104	100-280	600-880		80-290
TN (mg/l)	5-17	6-21	0.31-74	25-45.2	20-85
TP (mg/l)	0.1-2			17.2-27	4-15
PO_4 (mg/l)	0.94-48.8	4-171	12.7-32		
NH_3 (mg/l)	<0.1-15	0.04-11.3	0.005-6		12-50
NO_3 (mg/l)	0.28-6.3	0.4-2	0.3-5.8	0-5.8	0-0

Source: WateReuse Research Foundation project 10-02

Even though graywater sources exclude toilet wastes, fecal indicator bacteria can indirectly be introduced into the graywater stream when showering, washing hands or doing laundry. These indicator bacteria are found in concentrations that suggest there is a potential health risk reusing untreated graywater as shown in Table 2.3 (Maimon et al, 2010). Microbial bacteria of concern in graywater include: enterotoxigenic *E. coli*, *Salmonella*, *Shigella*, *Vibrio cholerae*, *Campylobacter*, and *Legionella*; protozoan such as Giardia and Cryptosporidium; and viruses such as enteroviruses, hepatitis A, rotavirus and Norwalk virus (Roesner et al., 2006). Instead of testing each pathogen, protozoan and virus, regulatory requirements test specific levels of indicator organisms such as total coliform, fecal coliform and *E. coli*. As described by Alkhatib (2008) the presence of organisms has been a major barrier that has discouraged acceptance of graywater use. Additionally, microbial quality of graywater can vary from household to household depending on a wide variety of factors. For example, Casanova et al. (2001) found a higher number of indicator organisms in households with children compared to households without. This may have been attributed to washing diapers and washing babies in the sink (Abu Ghumi et al., 2008). Therefore, reducing the paths of fecal exposure in graywater should be a priority to improve the quality of graywater.

Another area of concern for microbial concentration in graywater is the storage time. Due to the difference in timing patterns from graywater generation to graywater reuse, graywater may require storage. Due to the characteristics of high temperatures, nutrient rich and microbial indicators, graywater is subject to odors and growth of microorganisms if it is untreated. Multiple studies found adverse effects from storing graywater for a significant amount of time (Rose et al., 1991; Dixon et al., 1999). Within the first 24 hours of storage, settlement of suspended solids occurs improving the quality of graywater. However, after 24 hours there was an increase in fecal coliform. This suggests that untreated graywater shouldn't be stored for more than 24 hours to reduce indicator organism growth.

Table 2.3. Microbial Quality of Graywater

Reference	**Source**	**Total Coliforms (CFU/100mL)**	**Fecal Coliforms (CFU/100mL)**	***E.Coli* (CFU/100mL)**	**Enterococci (CFU/100mL)**
Eriksson et al., 2002	Bathroom graywater	70 - $2.4 x 10^7$	10^0 - $3.3 x 10^3$	$<10^2$ – 2.8^3	
Eriksson et al., 2002	Laundries	56 - $7 x 10^5$	9- $1.09 x 10^3$	$2.82 x 10^7$	
Eriksson et al., 2002	Composite graywater	$10^{7.2}$ – $10^{8.8}$	$10^{5.4}$ – $10^{7.2}$	10^0 – 2.36^8	9 - $2.7 x 10^5$
Rose et al., 1999	Showers	10^5	$6 x 10^3$		
Rose et al.,	Laundries	199	56		

1999					
Rose et al., 1999	Rinse water	126	25		
Rose et al., 1999	Composite Graywater	2.8×10^7	1.8×10^4- 7.9×10^6		
Casanova et al., 2001	Graywater including kitchen sink		8.84×10^4		
Casanova et al., 2001	Graywater excluding kitchen sink		8.22×10^2		
Winward et al., 2008	Composite Graywater	5.4±0.8[a]		2.8±0.8[a]	2.8±0.9[a]
Ottoson and Stenstrom, 2003	Composite Graywater	7.9[a]	5.8[b]		2.4 [a]

[a]numbers calculated in $\log_{10}$ CFU/100mL
[b]Thermotolerant coliforms in $\log_{10}$ CFU/100mL

2.3 Public Health and Environmental Issues Associated with Graywater Reuse

Due to the physical, chemical and microbial characteristics of graywater there is a potential to cause public health and environmental issues if graywater isn't used appropriately. The potential paths of exposure include ingestion of graywater, indirect ingestion of graywater (located on the surface of edible plants) or peripheral vectors like mosquitoes or pets (Maimon et al., 2010). Additionally, the public health and environmental impacts vary for each end application of graywater. When the end use is irrigation, both public health and environmental impacts are of concern. However, when graywater is used for toilet flushing, the only area of concern is public health. Additionally, the health concern is more prominent in toilet flushing applications since human contact may be difficult to avoid. Interestingly, current graywater literature identifies only the issues with ingesting graywater through irrigation exposure and doesn't fully investigate toilet flushing applications.

The degree of exposure is critical in quantifying the health risks associated with graywater exposure. As stated in Dixon et al. (1999), a qualitative approach to developing a graywater regulation can be developed through components of hazard, dose response and exposure (Table 2.4). Systems that are small in population, incorporate a physical barrier, and contain small bacteria concentrations are considered to be low risk scenarios. One issue with this particular table is the duration before reuse scale. Indicator organisms have been proven to grow in untreated storage (Rose et al. 1991), but there is some debate on whether or not increasing storage time increases the risk due to viruses. In a study conducted by Rose et al. 1991, hazardous viruses such as poliovirus did not increase during storage. Therefore, while indicator organisms may increase during storage, viruses may not. This has lead multiple authors to the conclusion that indicator organisms provide an overestimation of the risks associated with reusing graywater (Ottoson and Stenstrom, 2003; Roesner et al., 2006).

Table 2.4 Qualitative Risks Associated with Graywater (Dixon et al., 1999)

	Lower Risk	Intermediate Risk	Higher Risk
Population	Small population (residential)		Large population (multi-residential/commercial)
Exposure	No body contact (subsurface irrigation)	Some contact (toilet flushing/bathing)	Ingestion (drinking)
Dose-response	<1 virus per sample <1 bacteria per sample		>1 virus per sample $>10^6$ bacteria per sample
Delay before re-use	Immediate re-use	Re-used within hours	Re-used within days

2.4 Health Issues Associated with Graywater Reuse for Toilet Flushing

One of the prominent issues with clarifying the health issues associated with toilet flushing is the current graywater literature only addresses irrigation exposure scenarios. It has been accepted that graywater should use a form of disinfection prior to being reused for toilet flushing due to the exposure of pathogens and viruses. However, it is not well understood to what extent and if a form of biological treatment is necessary. A study conducted by Baker and Bloomfield (2000) evaluated the persistence of viruses in a bathroom. The study examined the persistence of one specific virus, *salmonella* when seeded on a toilet seat using potable water. The presence of the bacteria was prominent 50 days after the seeding, suggesting the resilience and durability of viruses to survive in the bathroom environment. This study also supports the notion that there is potential for toilets using potable water to serve as a vector for exposure to pathogens and viruses if an ill person were to use the facility. Since organisms present in toilet water can volatize and persist, this study reinforces the importance of disinfecting toilet water. However, when graywater is properly disinfected and dosed with an appropriate concentration of residual, there is no reason to believe that graywater would contribute more to the presence of pathogens and viruses compared to potable water.

Another issue that isn't well documented is the level of acceptable disinfection or indicator organisms, whether graywater, potable water or reclaimed water. Future research in graywater literature needs to address this concern. Such studies would offer a scientifically sound argument for the development of water quality requirements for treated graywater.

2.5 Environmental Issues Associated with Graywater Irrigation

The chemical characteristics of graywater originate from a diverse array of products and chemicals used in a variety of personal care products. These particular products can be characterized as surfactants, detergents, bleaches, dyes, enzymes, fragrances, flavorings, preservatives and builders (Roesner, 2006). A study conducted by the National Institute of Health (2004) evaluated the chemicals in household products and found 2,500 different chemicals in 5,000 products. Many of these products can end up in the graywater stream and thus end up getting used for irrigation. The main areas of environmental pollution are caused by increased levels of salinity, boron and surfactants altering the properties of soil, damaging plants and contaminating groundwater supplies (Gross et al., 2005).

2.5.1 Salts

The characteristics of graywater demonstrate concentrations of salt based on high levels of pH, sodium adsorption ratio (SAR) and electrical conductivity. When soils are exposed to high sodium waters, the physical condition of the soil can degrade and harm salt sensitive plants. Misra and Sivongxay (2009) found a slight reduction in saturated hydraulic conductivity of soils exposed to saline waters. However, only after soils reach a SAR value of 13 or more, the permeability and aeration can be reduced to a level of concern. Sharvelle et al. (2010) evaluated SAR values from households located in California, Texas, Colorado and Arizona who have been irrigating with graywater for a minimum of five years and found all SAR values were lower than 3.5. Even though the results of this study didn't find any negative impacts, care should be taken when irrigating with untreated graywater. For example, irrigating salt tolerant plants with graywater versus non-tolerant plants can produce more plant growth. For more information on this reference WateReuse Research Foundation Report 10-02.

2.5.2 Boron

Boron can be found in a variety of laundry detergents and is a micronutrient to plants in small portions. However, soils containing more than 5 to 8 mg/l of hot water soluble boron may require revegetation (Nable et al., 1997). One study conducted by Gross et al. (2005) recommended boron concentrations between 0.3 mg/l and 1.0 mg/l for non-tolerant plants. However, composite graywater in the same study was found to range between 0.1 to 1.6 mg/l. This suggests a potential negative impact on plant health at high concentrations, yet at low concentrations there may be no negative impacts. Instead of regulating boron concentrations, Australian regulators provide recommendations on boron free detergents that can reduce the initial quality of graywater. Improving the initial quality of graywater can reduce the negative impacts on both public health and the environment. However, this involves a voluntary homeowner change and can’t be regulated.

2.5.3 Surfactants

When exposed to soils, surfactants can alter the hydraulic conductivity. Surfactants originate from laundry detergent in the form of anionic (linear alky benzene sulfonates (LAS), alcohol sulfates or alkyl sulfates (AS), and alcohol ether sulfates or alkyl ethoxy sulfates (AES)) and nonionic (alcohol ethoxylates (AE)). A study conducted by Wiel-Shafran et al. (2006) found average surfactant concentrations in graywater to be high compared to wastewater due to the source of surfactants primarily from laundry waters. Additionally, concentrations of 250 mg/l of surfactants are typically considered to be toxic to plants (Garland et al., 2004). However, the average concentration of surfactants ranged between 0.7 and 70 mg/l, well below the concentration for toxicity. Similar to salt levels, care should be taken in the quantity of surfactants exposed to the environment.

2.5.4 Fate of Pathogens in Soil

Another area of concern when using graywater for irrigation is the fate and persistence of pathogens in soils. After using graywater for irrigation there is a potential for contaminants to leach into groundwater supplies and contaminate water sources (Roesner et al., 2006). In order for this interaction to occur, pathogens must survive in the soil media. Sharvelle et al. (2010) evaluated fecal indicators in soil from households irrigating with graywater for a minimum of 5 years from California, Arizona, Texas and Colorado. *E. coli* was detected in all graywater irrigated areas with an average concentration of 11 cells per gram of soil. However, *E.coli* concentrations of 9 cells per gram of soil were also detected in control areas irrigated with freshwater. Therefore, it was found that there wasn't a consistency between soils irrigated with graywater and an increase in *E. coli* concentrations. As discussed by Roesner et al. (2006), it isn't well known if pathogens from graywater irrigation applications may contaminate groundwater sources, yet due to the variation in distances between applications of graywater and the small quantities used, there is a small threat to groundwater pollution.

2.5.5 Environmental Issues for Graywater Irrigation Findings

Research on health and environmental impacts of graywater reuse is primarily available for irrigation applications. The characteristics of graywater in terms of boron, surfactants, oil and grease and salts make reusing graywater for irrigation a potential environmental hazard on plant health and soil conditions. Instead of requiring specific levels of treatment, many regulatory agencies have adopted best management practices (BMPs) to mitigate these concerns. One effective way to reduce environmental impacts is to improve the initial quality of graywater by using products low in boron, salts and surfactants (www.azdeq.gov/environ/water/permits/download/graybro.pdf). Additionally, excluding high pollutant graywater sources such as kitchen wastes from the graywater stream can improve initial quality due to the high concentration of organics, oil and grease and indicator organisms.

The primary concern for public health issues associated with reusing graywater for irrigation is the potential pathways of human exposure. Instead of imposing strict water quality requirements, if graywater is applied through drip or subsurface irrigation it greatly reduces exposure routes. Such recommendations are also an integral part of recommended BMPs (www.azdeq.gov/environ/water/permits/download/graybro.pdf).

CHAPTER 3 GRAYWATER TREATMENT

There are a wide variety of commercially available graywater systems for the treatment of graywater. Since regulations are different based on end application, the type of treatment should be dependent on the water quality requirements. Therefore, the treatment of graywater can be divided among two categories: 1) systems designed to treat graywater for irrigation; and 2) systems designed to treat graywater for toilet flushing. One objective of WateReuse Project 10-02 was to gather data on commercially available graywater systems in terms of water quality achieved, system reliability, and required maintenance. In order to document this type of information from commercial manufacturers, a survey was constructed to evaluate the type of treatment employed, required maintenance, and a list of system owners to contact and discuss the system directly. A total of 31 commercial manufacturers were contacted, 14 of which market a graywater system designed for irrigation (Table 3.1), and the other designed for either toilet flushing or irrigation (Table 3.2). Additionally, many homeowners have put together their own systems and this type of system is acceptable based on Arizona regulations. Therefore, this type of system was included in the analysis.

The types of systems available for irrigation include diversion devices, filtration and biological treatment as documented in Table 3.1. Diversion devices act as collection tank operating on a pump or by gravity to collect and redistribute graywater to an irrigation field. While these types of systems are commercially available, many homeowners elect to construct their own diversion devices. As discussed by Bergdolt et al. (2011) a homebuilt system should include a storage tank, filter and pump to distribute graywater to an irrigation system. In addition, graywater tanks should be equipped with an inlet, overflow pipe and a drain line to safely operate. Prior to entering the graywater irrigation system, a filter should remove large particles to prevent blockage and buildup within the irrigation system. The advantage of minimal treatment was found to be low maintenance and low cost (low energy requirements). However, this also produces a low quality of water. Therefore, the effective use of these systems should be small in scale (residential) and intended for irrigation (drip or subsurface).

Table 3.1 Summary of Commercially Available Irrigation Systems

	Storage tank	Filtration	Treatment	Residential or commercial applications
Diversion Devices (6.1.1)				
Envirosink			None	Residential
White International		✓	Breather filter	Residential
NutriCycle	✓		None	Both
Eco Design			None	Residential
Filtrex	✓		None	Both
GreytoGreen	✓	✓	Lint catcher	Residential
Waterwise Systems	✓	✓	Lint catcher	Both
Physical Treatment (6.1.2)				
Just Water Savers	✓	✓	Filtration to 400 microns	Residential
Just Water Solutions & WaterWise Group	✓	✓	Matala filtration	Residential
The Natural Home	✓	✓	Filter	Residential
Wattworks Smartpit	✓	✓	Two stage filtration (2 mm and 0.8 mm mesh)	Residential
Ecological Engineering	✓	✓	Filter bed	Residential
ReWater	✓	✓	Sand filter vessel	Both
Biological Treatment (6.1.3)				
Everhard Industries	✓		Aeration	Residential

If the intended end use for graywater is toilet flushing, all commercially available systems utilize a form of disinfection. Not only to meet regulatory requirements, but it is generally accepted graywater should be disinfected prior to reuse for toilet flushing (U.S. EPA, 2010). Therefore, increasing treatment means an increase in maintenance and cost. However, these systems can treat graywater to a higher quality. The types of available technologies documented in the survey include filtration/disinfection systems, treatment wetlands, biological treatment and reverse osmosis as displayed in Table 3.2. Filtration/disinfection systems are designed to meet the minimum plumbing code requirements. Therefore, the maintenance requirements are fairly simple only requiring cleaning the filter and ensuring sufficient quantities of disinfectant. Interestingly, all the manufacturers who reported water quality results noted an inability to treat organics in graywater (BOD, TSS and Turbidity), yet were more effective at controlling the indicator organisms (fecal coliform). Therefore, if regulations require a strict BOD and TSS levels, a filtration/disinfection system will not work.

Table 3.2 Summary of Commercially Available Toilet Flushing Systems

	Storage tank	Filtration	Treatment	Residential or commercial applications
Diversion Devices (8.1)				
Sink Positive			None	Both
Filtration and Disinfection (8.2)				
Sloan Valve	✓	✓	80 µm filter/chlorine	Both
BRAC	✓	✓	100 µm filter/chlorine	Both
Wahaso	✓	✓	5 µm filter/chlorine	Commercial
Water Legacy	✓	✓	Hydrogen peroxide/ultraviolet	Residential
AquaRecycle	✓	✓	100 and 3µm filter/ozone	Commercial
Biological Treatment (8.3)				
GROW system			Hybrid reed beds	Both
Rootzone Australia			Subsurface rootzone filter	Residential
Earthsafe	✓	✓	Sequencing batch reactor/ultraviolet	Residential
Ozzi kleen	✓	✓	Sequencing batch reactor/chlorine	Residential
Nubian	✓	✓	Aerated biofilter/ultrafiltration/ultraviolet/chlorine	Both
AquaClarus	✓	✓	Membrane bioreactor/ultraviolet	Residential
AquaCell	✓	✓	Membrane bioreactor/ultraviolet /chlorine	Both
Water Gurus	✓	✓	Membrane bioreactor/ultraviolet	Residential
Wastewater Australia	✓	✓	Membrane bioreactor/ultraviolet	Residential
Ovivo	✓	✓	Membrane bioreactor	Commercial
Reverse Osmosis (8.4)				
Equarius	✓	✓	Aeration/ 1 µm filter/ozone/reverse osmosis	Residential

All the treatment wetlands and biological systems found in the research effectively treated graywater to a high quality (< 20 mg/l BOD, <20 mg/l TSS, and <10 cfu/100ml *E.coli*). The types of biological treatment include sequencing batch reactors, membrane bioreactors and biological aerated filters. While all these particular technologies effectively treated graywater, systems that incorporated a form of physical and biological treatment resulted in the highest water quality; for example, membrane bioreactors. However, the energy required to run a biological system in conjunction with a form of disinfection was found to be substantially higher indicating a higher operating cost.

An interesting note about biological treatment of graywater as analyzed by Jefferson et al. (2001) is the effectiveness of biological treatment. When tested with both graywater and blackwater, it was found that membrane bioreactor were able to treat the blackwater to just as high of quality as the graywater. This suggests that advanced biological treatment, especially when equipped with a disinfection unit can easily treat blackwater. In essence, these particular systems act as small wastewater treatment plants and have the capability to treat wastewater. The question becomes does graywater require that high of treatment to truly protect public health? For more information on graywater treatment systems and survey results please see chapters 7 and 8 in WateReuse Project 10-02.

CHAPTER 4 GRAYWATER REGULATIONS AND STATE SURVEY FINDINGS

4.1 Introduction

As the reliability of municipal water resources become more stressed from population increase, drought and climatic change, utilities are looking toward new concepts for water management. One strategy for reducing freshwater demands that is gaining popularity is the reuse of graywater for nonpotable applications. Graywater, defined as wastewater from lavatory sinks, showers, bathtubs and laundry machines, and excluding wastewater from dishwashers, kitchen sinks and toilets has the potential to substantially reduce fresh water demands (Roesner et al, 2006; Maimon et al. 2010). Graywater compromises between 50 – 80% of domestic water consumption, and can be reused for toilet flushing or irrigation with simple treatment to reduce the stress on natural water systems (Gross et al. 2007). In addition, the characteristically low organic content of graywater renders it suitable for nonpotable applications with minimal treatment (Pidou, 2006).

The quality of graywater characteristics has been well studied (Eriksson et al., 2002) and has been determined to contain pathogens and viruses which may pose human health risk through direct or indirect exposure and peripheral vectors such as mosquitoes (Maimon et al. 2010). Additionally, when graywater is reused for irrigation concentrations of boron, salts, surfactants, oil and grease and nutrients may create harmful environmental effects by altering the properties of soil, damaging plants and contaminating groundwater sources (Gross et al., 2005). However, the risks posed to human health and the environment when reusing graywater for irrigation has been well studied (Maimon et al., 2010). Instead of strictly regulating graywater, many regulatory agencies have adopted best management practices (BMPs) to mitigate the concerns for environmental exposure and public health. One effective way to reduce environmental impacts is to improve the initial quality of graywater by using products low in boron, surfactants and salts. Additionally, excluding high pollutant graywater sources such as kitchen wastes from the graywater stream can improve initial quality due to the high concentration of organics, oil and grease and indicator organisms.

The risks posed to human health by reusing graywater for toilet flushing remain largely unknown. When toilet flushing is the end use for graywater, the potential exists for human contact with graywater, and thus the primary concern is the presence of pathogens and viruses. Public health officials who are not familiar with graywater reuse tend to view it as a health risk that must be avoided; those that are more knowledgeable about graywater and the public health risks are divided about its public health threat. It has been accepted that graywater treatment should employ a form of disinfection prior to being reused for toilet flushing due to the exposure of pathogens and viruses (U.S.E EPA, 2010). However, it is not well documented what the level of acceptable disinfection or indicator organisms truly are. Therefore, a majority of states have adopted regulations similar to reclaimed water requirements for toilet flushing.

The degree of exposure is also critical in quantifying the health risks associated with graywater exposure. As stated in Dixon et al. (1999), a qualitative approach to constructing graywater regulations can be developed through components of hazard, dose response and exposure. Systems that are small in population, incorporate a physical barrier to graywater (subsurface irrigation) and contain small bacteria concentrations are considered to be low risk scenarios. This suggests that graywater regulations should be dependent on scale (commercial versus residential) and application (toilet flushing versus subsurface irrigation). In the United States, California, Arizona, New Mexico and Texas have led the graywater movement with state regulations already in place and many examples of installed graywater systems. However, despite the prevalence of graywater reuse, most current regulations have many discrepancies and states looking into developing regulations and guidelines on the safe reuse of graywater are seeking guidance on doing so.

The objective of this paper is to compile information on currently available regulations for integrating graywater systems into various types of localized sites. The data gathered will help regulatory agencies make informed decisions based on the experiences of others. Additionally, this study focuses on the public health, environmental and regulatory issues associated with graywater reuse. A review of current regulations on graywater was conducted and a survey was administered to both states that regulate graywater and states that lack a graywater regulation to identify viewpoints, experiences and thoughts on graywater and graywater regulations. The goal of this study is to begin to understand effective approaches for regulating graywater and identify the barriers to widespread implementation of graywater reuse systems.

4.2 Methodology

A survey was developed in order to document the experiences, viewpoints and attitudes of graywater reuse. The survey consisted of two prototypes, one designed for states that regulate graywater and the other designed for states that do not regulate graywater. Three questions were designed using a knowledge, attitudes and practice (KAP) survey that was administered to both groups in regards to issues associated with developing graywater regulations, enforcing graywater regulations and whether or not they support graywater reuse. States that regulate graywater were asked questions in regards to current regulations (permit process, system monitoring, what is effective and what needs improvement). Additionally, states were asked if they had received any public health or environmental complaints associated with using graywater. States that did not regulate graywater were asked what their views of public health and environmental issues are associated with graywater reuse. Additionally, surveyors were asked to identify the hurdles and steps that need to occur in order to make graywater legal. This information can provide insight on the issues associated with graywater regulations and what current regulators have implemented that are effective from a public health, environmental and regulation enforcement perspective. For a full list of the survey questions, see Appendix A.

In April, 2012, the survey was constructed online using surveymonkey.com and sent to 50 state and utility agencies from 25 states. The entities selected in the process consisted of states that both allow graywater reuse and do not allow graywater reuse from all regions of the United States. Additionally, to gain an understanding of both state and city perspectives, attempts were made to survey a state agency and utility from the same state (Figure 4.1). Survey respondents also had the opportunity to receive a word processing document via email and fill out the form and send it back via email. To provide incentive to participate in the survey, individuals completing the survey received a complete document of the findings. The format of surveymonkey.com allowed processing of the data into a Microsoft Excel file where findings could be analyzed and divided among regions (Midwest and Northeast, South, and West).

A total of 41 states, counties and city utilities completed the survey as displayed in Figure 4.1. 24 of which are located in a state that regulates graywater and 17 are located in a state that does not regulate graywater or lacks a graywater regulation. Additionally, 21 state agencies responded and only 20 cities and counties responded. There is, however, still a diverse array of states that have adopted and not adopted graywater regulations that provides a varying degree of experiences and views on graywater reuse.

4.3 Current Graywater Regulations

To date, there are 20 states that allow a form of graywater reuse (Figure 4.1), but the regulations adopted are vastly different for each state. Graywater regulations fall under many regulatory codes, the two most common include plumbing codes and health codes. Many states have adopted a plumbing code such as the Uniform Plumbing Code (UPC), the International Plumbing Code (IPC) or the National Standards Plumbing Code which all identify procedures for implementing a graywater system. However, adopting a plumbing code that includes graywater reuse does not necessarily mean graywater is allowed for reuse. For example, West Virginia has adopted the 2009 IPC including graywater requirements. However, the Department of Health and Human Resources (DHHR) does not allow graywater reuse. Therefore, any discrepancies between the plumbing code and Health Department laws give precedence to the Health Department. Additionally, local regulators such as cities or counties may enforce stricter graywater regulations compared to state codes.

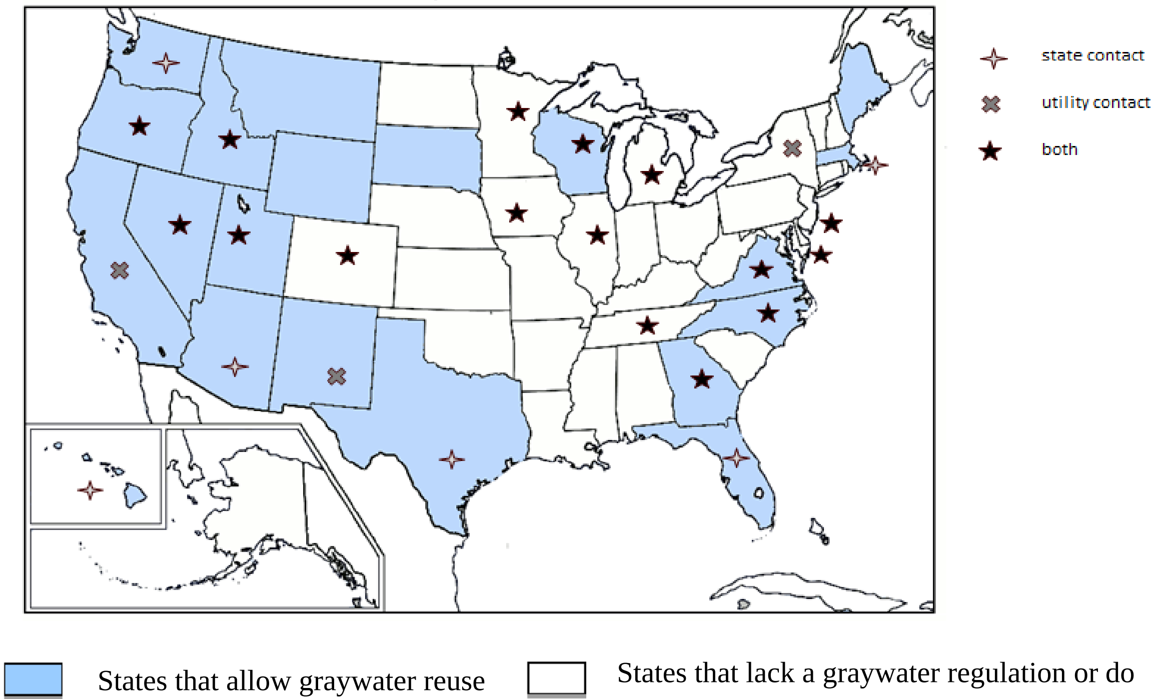

Figure 4.1. States Responding to Graywater Survey

The available graywater regulations have been divided into three different sections: 1) tiered graywater regulations; 2) non-tiered graywater regulations; and 3) residential irrigation regulations. The tiered approach to graywater provides different requirements based on the quantity of graywater generated. As flow increases, the regulation requirements change. Non-tiered graywater regulations don't distinguish between flow quantities and only sometimes distinguish between residential and commercial applications. Additionally, both tiered and non-tiered regulations for irrigation use are often different from toilet flushing applications. Residential irrigation regulations only identify graywater reuse for residential irrigation.

4.3.1 Tiered Graywater Regulations

Five states (Arizona, California, New Mexico, Oregon, and Washington) have developed a tiered approach to regulating graywater. This constitutes varying regulatory requirements based on quantity of water being reused and the application (irrigation or toilet flushing). The regulations adopted have significantly different approaches to water quality, permitting and tier requirements (Table 4.1). For example, Arizona, New Mexico and California have developed a permit-by-rule regulation with best management practices (BMPs) that residents must follow. If these basic BMPs are followed, no permit is required prior to constructing a graywater system. The BMPs aim at protecting public health and the environment and are only applied to small flow irrigation applications. Typical BMPs found in all regulations include:

1. Graywater cannot be stored for more than 24 hours
2. Graywater must not be sprayed and should be applied through drip or subsurface irrigation
3. Minimization of public exposure/ponding must be practiced

The states that have adopted BMPs for low flow applications (Arizona, New Mexico, and California) have a similar definition for graywater; it cannot contain wastewater from kitchens. Kitchen wastewater has a higher concentration of organics, oil and grease and indicator organisms that negatively impacts the initial quality of graywater (Alkhatib et al., 2008), thus rendering the water undesirable for reuse without treatment. However, Oregon and Washington have included kitchen wastewaters in the regulations, yet regulate these sources with different requirements. For example, in Washington if kitchen wastewater is included, graywater is considered to be "dark graywater" and must meet different quality requirements compared to graywater without kitchen sources. In contrast, Oregon requires any kitchen water used must pass through a form of physical treatment (filters, sand filtration, etc.) prior to being used. Differences in graywater definition have a prominent effect on the public health and environmental perspectives of graywater. Maintaining a consistent definition of graywater is critical in reducing discrepancies between graywater regulations.

Another discrepancy in graywater regulations is what states consider to be a large enough flow to require a permit. To minimize the potential health risks in large systems, a predetermined flow limit is enforced. If systems exceed the flow limit, a permit is required to operate and thus requires departmental approval. For example, Arizona does not require a permit on systems less than 400 gpd and New Mexico does not require a permit on systems less than 250 gpd. California has taken a step further to create a tiered approach that is dependent on the source of graywater. When residents only use laundry wastewater, no permit is required; however, if bathroom graywater and laundry water are used, the state requires a permit. As discussed by Maimon et al. (2010) applications in multi-residential and commercial applications increases the risk of spreading pathogens and viruses and should therefore be the criteria for level of treatment, rather than the volume of water generated.

Table 4.1 Summary of Tiered Graywater Regulations (NR – Not Regulated)

State	Tier 1			Tier 2			Tier 3		
	Flow (gpd)	**Water quality**	**Permit**	**Flow (gpd)**	**Water quality**	**Permit**	**Flow (gpd)**	**Water quality**	**Permit**
Arizona									
Irrigation	400	None	No	400 – 3000	None	Yes	more than 3000	NR	Yes
Toilet flush		NR	NR		NR	NR		NR	NR
California[a]									
Irrigation	<250	None	Yes	>250	None	Yes	non-potable use	NR	NR
Toilet flush		NR	NR		NR	NR		Yes	Yes
New Mexico									
Irrigation	<250	None	No	>2000	Yes	Yes	NR	NR	NR
Toilet flush		NR	NR		Yes	Yes	NR	NR	NR
Oregon									
Irrigation	<300	Yes	Yes	300 - 1200	Yes	Yes	>1200[b]	Yes	Yes
Toilet flush		NR	NR		NR	NR		Yes	Yes
Washington									
Irrigation	<60	None	Yes	<3500	None	Yes	<3500	Yes	Yes
Toilet flush	Regulated under Chapter 51-56 (plumbing code).Must receive approval and have minimum treatment of filtration/disinfection								

[a] California allows laundry effluent to be directly disposed to an irrigation system without a permit
[b] For toilet flushing purposes, this quantity does not apply. Flows can be less than 1,200gpd.

An interesting note is that in Arizona, New Mexico and California system maintenance is entirely dependent on the homeowner adhering to the BMPs since no permit is required. Therefore, if a user is not following the rules, there is no way to enforce safe operation of a system. These states have limited concern over enforcement of single residential systems since educational materials on safe operation of a graywater system are readily available, and exposure to graywater is limited to the homeowners. One approach taken by Oregon that addresses enforcement of system maintenance is requiring an annual fee and submittal of a report on the system. If homeowners submit the appropriate document, the annual fee can be waved, thus providing incentive to submit the report on system maintenance. However, since Oregon recently adopted graywater regulations (April, 2012), it is unknown if this method is effective.

One consistent rule with the tiered graywater regulations is requiring a permit on systems that are multi-residential/commercial scale or high exposure categories such as toilet flushing. When graywater reuse results in high exposure scenarios, states require a formal permit process and systems must meet specific water quality requirements. However, the water quantity and quality requirements differ substantially. For example, Oregon requires any system over 300 gpd to achieve advanced secondary treatment (10 mg/l BOD and 10 mg/l TSS) and if graywater is used for toilet flushing, it must be disinfected and meet a total coliform concentration of 2.2/100ml. This particular requirement is stricter treatment requirements compared to the national standards for secondary treatment of wastewater. Additionally, California, does not require removal of organics, but requires graywater to be filtered and disinfected. The disinfection is the same and Oregon and must meet disinfected tertiary recycled water quality of 2.2 MPN/100ml total coliform. Finally, in contrast to both these states, Washington has adopted the International Plumbing Code for treatment and use of toilet flushing graywater. The water quality requirements only indicate a form of filtration, disinfection and coloring is required.

4.3.2 Non-tiered Graywater Regulations

Many States have adopted graywater regulations, but do not provide requirements based on the scale of system. These states include Florida, Georgia, Massachusetts, Montana, North Carolina, South Dakota, Texas, Utah, Virginia, Wisconsin and Wyoming (Table 4.2). Many of these states have applied the regulations from reclaimed water to graywater applications. For example, Wisconsin and Massachusetts require graywater to meet the same water quality requirements as reclaimed wastewater regardless of end application. This means both toilet flushing and irrigation applications must achieve reclaimed water standards. This process may seem to be interchangeable, yet graywater differs from reclaimed water since small applications such as residential reuse does not leave the land it was generated on. In addition, graywater is applied through drip irrigation where human contact can be minimized. In comparison, reclaimed water is supplied to multiple users and can be applied via spray irrigation. These states have simplified the process by assuming graywater and wastewater reuse is the same and thus requires the same treatment.

Instead of adopting reclaimed water requirements, some states such as Florida, Georgia, and Utah have adopted the minimum water quality requirements through the plumbing code. Georgia requires filtration to reduce the turbidity to 10 NTU and the disinfection to reduce fecal coliform to 500 cfu/100ml. Additionally, Utah and Georgia require a residual chlorine concentration to remain in the graywater.

Table 4.2. Summary of State's Graywater Regulation Allowing Multiple Forms of Use (NR is defined as not regulated; NS is defined as none specified)

State	Residential			Commercial		
	Flow (gpd)	Are there Water quality requirements	Permit required ?	Flow (gpd)	Are there Water quality requirements	Permit required ?
Florida						
Irrigation	< 1500	ANSI/NSF Standard 40	Yes	< 1500	ANSI/NSF Standard 40	Yes
Toilet flushing	NS	Yes	Yes	NS	Yes	Yes
Georgia						
Irrigation	< 2000	Yes	Yes	< 2000	Yes	Yes
Toilet flushing	NS	Yes	Yes	NS	Yes	Yes
Massachusetts						
Irrigation	NR	NR	NR	NS	Yes	Yes
Toilet flushing	NR	NR	NR	NS	Yes	Yes
Montana						
Irrigation	NS	No	Yes	NS	No	Yes
Toilet flushing	NS	No	No	NS	No	No
North Carolina						
Irrigation	NS	No	Yes	NR	NR	NR
Toilet flushing	NS	Yes	Yes	NR	NR	NR
South Dakota						
Irrigation	< 7500	No	No	< 7500	No	No
Toilet flushing	< 7500	No	No	< 7500	No	No
Texas						
Irrigation	400	No	No	NS	Yes	No
Toilet flushing	NR	NR	NR	NS	Yes	No
Utah						
Irrigation	NS	No	Yes	NS	Yes	Yes
Toilet flushing	NS	Yes	Yes	NS	Yes	Yes
Virginia						
Irrigation	NS	Yes	Yes	NS	Yes	Yes
Toilet flushing	NS	Yes	Yes	NS	Yes	Yes
Wisconsin						
Irrigation	NS	Yes	Yes	NS	Yes	Yes
Toilet flushing	NS	Yes	Yes	NS	Yes	Yes
Wyoming						

Irrigation	< 2000	No	No	< 2000	No	No
Toilet flushing	< 2000	No	No	< 2000	No	No

4.3.3 Residential Graywater Regulations

Hawaii, Idaho, Maine and Nevada have adopted graywater regulations that only address residential subsurface irrigation. This particular regulation is more common due to the low risk/low exposure application of graywater. The regulations adopted by these entities are consistent, requiring a permit to ensure BMPs are being followed at all times. Additionally, most entities enforce water quality requirements, except for Maine. Typical BMPs included in the graywater regulations are:

- Graywater cannot surface
- Graywater cannot be used for any purpose aside from subsurface irrigation
- If graywater tanks are used, the tank must be equipped with a three-way diversion device, that is connected to an approved sewer system
- If graywater tanks are used, the tank must include an overflow pipe, sized the same as the inlet pipe
- Graywater must be used on the same site it was generated
- If a backup water supply is used it must be equipped with an approved backflow prevention device
- Graywater cannot be used to irrigate edible plants

One of the concerns when exposing untreated graywater for irrigation is the deterioration of plant health. One resource that both Hawaii and Idaho provide is recommendations on salt tolerant plants that are likely to thrive when irrigated with graywater. Both Idaho and Hawaii do not require treatment prior to using graywater and therefore soils and plants can be exposed to high salinity graywater. Instead of implementing strict water quality requirements, these agencies have provided educational resources that allow users to understand the advantages and disadvantages of using untreated graywater for irrigation. Similarly, Sharvelle et al. (2010) analyzed a variety of plant tolerance to graywater in terms of crown density, dieback, foliage color, foliar burn, foliar necrosis, leaf size and overall quality. Based on the results, Table 4.3 provides recommendations on the sensitivity of plant tolerance to graywater irrigation. Additionally, Hawaii provides recommendations on soaps, detergents and cleaners that are low in bleaches, softeners, boron and surfactants. Improving the quality of graywater generated can, in of itself reduce the pollutant load exposed to the environment.

Table 4.3. Examples of Plant Tolerance to Graywater

Very Tolerant to graywater	**Moderate tolerance to graywater**	**Moderately sensitive to graywater**	**Sensitive to graywater**
Juniper	California Valeriana	Mugo Pine	Scotch Pine
Euonymus	Plum Tree	Bearded Iris	Hass Avocado
Rose of Sharon			Lemon Tree
Chrysanthemum			
St. Augustine Grass			

4.3.4 Graywater Reuse for Toilet Flushing

The available water quality requirements for toilet flushing applications vary considerably from state to state. Generally, there are three different ways to regulate graywater toilet flushing applications: 1) adopt regulations similar to reclaimed water; 2) adopt plumbing code water quality requirements; and 3) construct independent regulations with a defined set of water quality parameters. States such as Massachusetts and Wisconsin have implemented the same water quality requirements compared to their reclaimed water requirements (Table 4.4). In comparison, some states have developed graywater regulations that are different from reclaimed water requirements, yet still provide a form of filtration and disinfection. As shown in Table 4.4, the water quality requirements for California, New Mexico, Oregon and Texas don't have any similarities to the adopted toilet flushing regulations for graywater. Some states feel biological treatment is necessary, where others only require graywater to be disinfected.

Finally, other states such as Washington and Florida have adopted the minimal water quality requirements of the plumbing code. This requires a form of filtration and disinfection. Typically, there are no specifications on type of filtration or quantities of disinfection. Many states do not address graywater reuse for toilet flushing due to the lack of guidance in addressing this application. Therefore, additional research is required to define the acceptable levels of indicator organisms for residential and multi-residential/commercial applications that truly protect public health. In addition, research needs to address whether or not organics removal is necessary for toilet flushing applications.

Table 4.4 Summary of Toilet Flushing Regulations

State	Regulation	BOD5 (mg/l)	TSS (mg/l)	Turbidity (NTU)	Total Coliform (cfu/ 100ml)	Fecal Coliform (cfu/ 100ml)	disinfection
California	Title 22 Section 60301.230				2.2		
New Mexico	Title 20.7.3.810	30	30			200	
Oregon	OAR Chapter 340 Division 053	10	10		2.2		
Georgia	Georgia Gray Water Recycling Systems Guidelines			10	500	100	
Texas	TAC Title 30 Chapter 210 Subchapter F					20	
Massachusetts [ab]	310 CMR 15.262	10	5	2		14	
Wisconsin[b]	Chapter Comm 82	200	5				0.1 – 4 mg/l residual chlorine

[a] Massachusetts also requires a total nitrogen for Class A reclaimed water of 10 mg/l
[b] Same requirements for reclaimed water as graywater

4.3.5 Australian Graywater Regulations

During the late 90s drought issues in Australia caused a drastic reduction in freshwater supplies. For example, Melbourne's reservoir capacity was at a system high in October 1996 (97.6%), yet after a decade of drought, the capacity diminished to a system low in 2009 (25.6%). In response, many state and city agencies limited freshwater consumption by enforcing water restrictions. Additionally, utilities began to provide rebates for installing water conservation devices such as low-flow appliances and graywater systems. Therefore, graywater reuse became a means to reduce freshwater demands and lift water restrictions. After adopting regulations, graywater reuse became very popular with 54% of Australians reporting using a form of graywater reuse by 2007 (Australian Bureau of Statistics, 2010).

Graywater in Australia is regulated at the state level, which is the only similarity between the United States and Australian regulations. There are three acceptable methods to reuse graywater in each state: 1) temporary bucketing of graywater/hose connections from the washing machine; 2) graywater diversion devices (GDD); and 3) graywater treatment systems (GTS). Bucketing and hose connections do not require a permit because they are considered to be small amounts of graywater reused for a short period of time. Therefore, the risk to public health is small. Additionally, this type of graywater application is the most common due to the ease of implementing these systems and the lack of regulatory hurdles. GDD's do not properly treat graywater, but instead act as a collection tank to redistribute graywater to a subsurface or drip irrigation system. Typically, there isn't a permit required to operate a GDD as long as BMPs are met and the system is installed by a licensed plumber. However, some states do require department approval prior to implementing this system. Typical BMPs include using graywater for subsurface or drip irrigation, not storing graywater for more than 24 hours and using garden friendly detergents. Additionally, GDD's must be maintained by homeowners.

GTS's collects and treats graywater to a predefined level which may be used for toilet flushing, irrigation and laundry water. In order to provide interested individuals with system information each state provides a list of GDD's and GTS's that meet the requirements for water quality. Manufacturers of GTS's interested in receiving department approval must undergo a 26 week trial period where graywater systems are tested for the water quality achieved. If the system meets the water quality requirements, the system is approved by the department and can be marketed and sold in the state. Only systems that have received state department approval can be used for its intended application. Since these systems are used for higher exposure scenarios (toilet flushing/laundry use) the long term sustainability of a graywater system is dependent on how the system is maintained. If the system fails to treat graywater, there could be detrimental effects to public health. Therefore, in order to address this issue, state department require individuals to sign into a tri-annual service contract. During the maintenance visitations, systems are thoroughly inspected, cleaned and repaired if needed. Since this particular application of graywater is more regulated and expensive due to the service contract, a majority of graywater applications are done via bucketing/hose connections and GDD's. However, the advantage of implementing this type of system is reducing the confusion of available systems. If there is an individual interested in installing a GTS, all the approved systems are available on the state department website. This is an easy and effective way to promote graywater systems to interested individuals. Instead of providing only the water quality requirements, the state provides systems that have met the water quality requirements.

Based on the experiences in Australia, the type of regulations that should be adopted support the tiered approach. For residential irrigation systems, graywater poses a small public health threat and therefore can be safely and effectively managed through BMPs and a permit-by-rule approach. However, once graywater is used for high exposure or high risk scenarios, graywater needs to be treated and the available systems need to be identified. Therefore, to reduce the confusion of system availability, states should supply system information instead of water quality requirements.

4.4 Survey Results

Based on the survey results, utilities and state agencies determined the highest priority associated with developing graywater regulations is public health (Figure 4.2). However, some agencies ranked the environment, water conservation, permitting/regulating, water law and inspection/maintenance as the highest priority when developing a regulation. Therefore, when developing a graywater regulation, all of these factors are critical, yet public health should be of utmost concern. To understand the health and environmental impacts of current graywater regulations, entities were asked to report the number of environmental and health complaints lodged. This begins to answer the question of whether or not graywater regulations are truly protecting public health and the environment. Interestingly, there was not a single health complaint filed due to the use of graywater. Additionally, there were no reports of complaints due to negative environmental impacts. However, just because there is a lack of reporting of illnesses and environmental issues from using graywater does not mean these problems do not exist. For example, an infected person/doctor may not be able to link the source of illness to graywater applications or contact with graywater. It should be made clear that graywater reuse to date cannot be distinguished from typical daily activities that result in the exposure to viruses and pathogens.

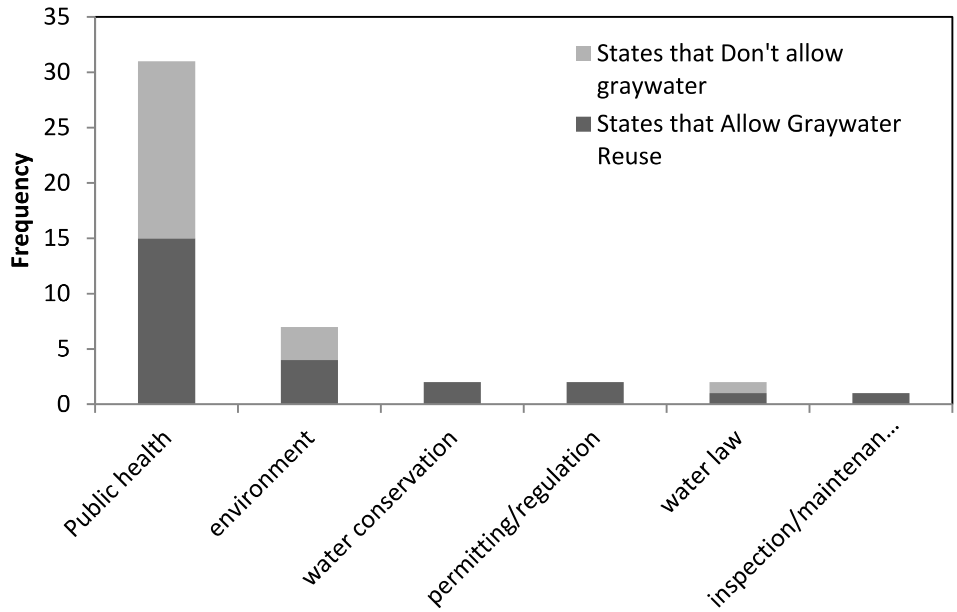

Figure 4.2 Highest priority issue associated with developing graywater regulations

While on the surface this particular result is promising, some entities have recently adopted graywater regulations and therefore the information is not as reliable. For example, Oregon adopted graywater regulations in April 2012 and filled out the survey March 2012. This implies that the regulation was not enforced when the survey was filled out. Nonetheless, states such as Arizona, with over 200,000 graywater systems in place for over 10 years, reported no illnesses or environmental complaints.

States that have adopted graywater regulations identified lack of resources as the largest issue associated with enforcing a graywater regulation (Figure 4.3). One issue with protecting public health and the environment is the long term sustainability of systems and how states organize permitting and maintenance. For example, if graywater regulations are adopted, but homeowners install unpermitted systems or systems out of compliance with code, this could jeopardize the protection of public health. However, implementing legislation that requires permits or annual inspection increases the amount of skilled labor needed by the state. Therefore, there must be a balance between increasing graywater system inspections and the available man power/resources. Adopting regulations that utilize BMPs with supporting educational resources on the safe reuse of graywater doesn't require as much manpower and internal resources as a strict permitting system. Some agencies may not be able to effectively implement graywater regulations to high risk scenarios, but still adopt regulations that can be safe with minimal labor. This may explain why some states adopt residential irrigation regulations only. Allowing the low risk, low exposure scenarios does not provide as big of a public health and environmental impact as, for example, commercial toilet flushing applications.

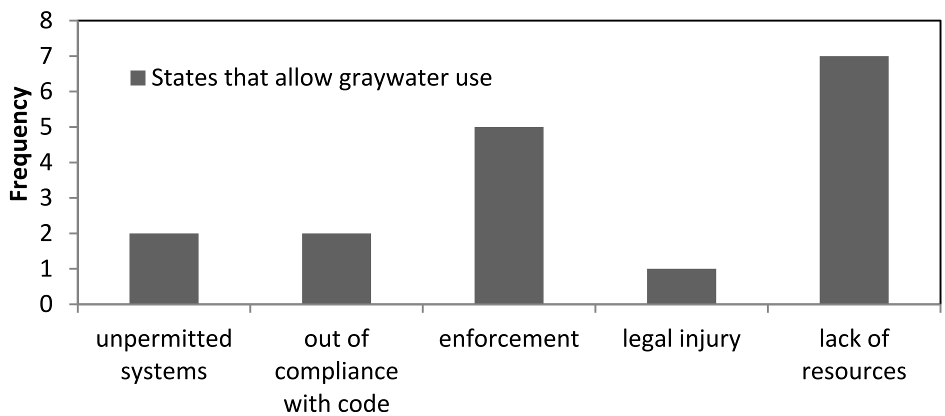

Figure 4.3 Issues reported with graywater reuse regulations from states that regulate graywater

States that currently do not regulate graywater perceived all choices to be an issue with graywater regulations (Figure 4.4). This implies these states foresee issues with unpermitted systems, systems out of compliance with code, enforcement, legal injury and lack of resources as the highest issue associated with graywater regulations. However, these particular states have not had direct experience with graywater regulations and therefore, special attention should be placed on the availability of resources and man power when developing a graywater regulation.

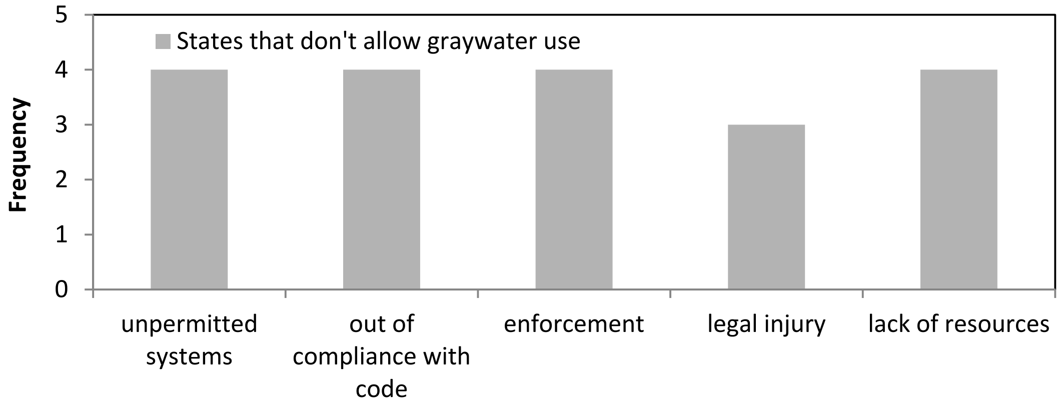

Figure 4.4 Perceived issues with graywater reuse regulations for states that do not allow graywater

4.5 Regional Differences

Adopting a graywater reuse regulation is primarily done to reduce water demands on natural systems. However, freshwater demands are significantly different depending on regions within the United States. For example, freshwater demands in California are different compared to Michigan. Therefore, the views on graywater and alternative water sources are different depending on geographic location. This was apparent in the results of the graywater survey. While some regions had differing views, a majority of regional states had a similar perspective.

4.5.1 The Midwest and Northeast

The Midwest and Northeast regions of the United States are considered to be water rich and are less concerned with water reuse strategies. In fact, one utility reported even though alternative water sources are encouraged, the entity is only at 60% water production capacity. Therefore, even though graywater reuse is generally supported in Midwest and Northeastern states (Figure 4.5), graywater regulations have not been pursued because there is no demand for them. Before regulations are adopted in this region, there is a general consensus that there needs to be a demand. The only two states that approve graywater reuse in the region are Massachusetts and Wisconsin. While Wisconsin supports the use of graywater, the regulatory process has discouraged the use of graywater by enforcing strict regulations.

The process includes product approval, plan approval, inspection and testing. However, one benefit to this strict regulation is the documentation. Wisconsin maintains an online database of approved graywater systems that is readily available to the public. However, due to the strict water quality requirements the wealth of system information is fairly limited. For more people to adopt graywater systems, the water quality requirements and process must be simplified to provide incentive to reuse graywater. Similar to Wisconsin, Massachusetts enforces strict regulations and permitting that has discouraged the use of graywater.

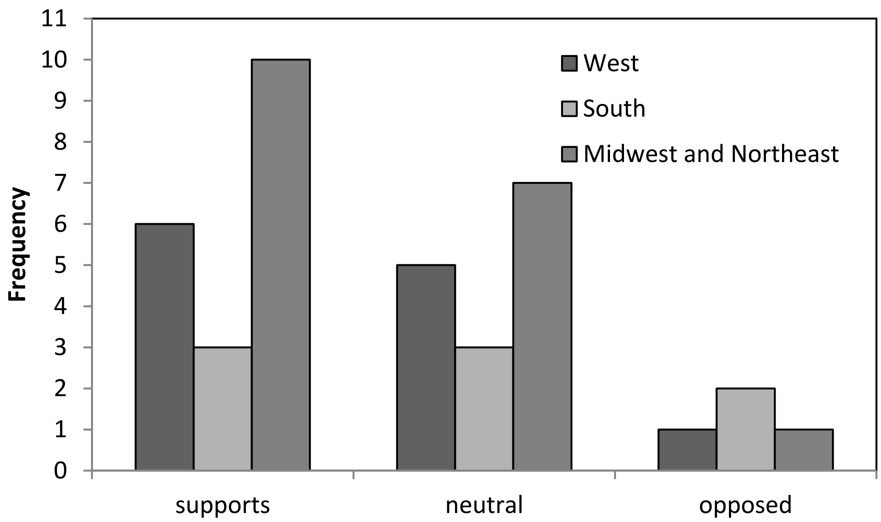

Figure 4.5 Survey results for whether states support or oppose graywater reuse

4.5.2 The South

The south has a diverse array of graywater perspectives, regulations and experiences. Florida, Georgia, Texas, Virginia and North Carolina all approve graywater use, but there are mixed views on supporting graywater reuse (Figure 4.5). While Virginia does approve graywater use, the state receives an annual precipitation of 45 to 55 inches. There is concern when combining untreated graywater with high precipitation for leaching nutrients and fecal coliform into the environment. Therefore, graywater reuse is not considered to be as cost effective nor beneficial to water savings compared to rainwater use. Another concern with graywater reuse as noted by Texas is an increase in BOD concentration in wastewater treatment plants due to water conservation. This particular issue has required cities to reexamine the capabilities of wastewater treatment plants in order to handle the higher concentrations. Whether or not this particular issue stems directly from graywater, the combination of water conservation and alternative water sources may negatively impact the quality of wastewater. However, these particular answers may not represent the typical views of graywater in the region. For example, there has been a greater incentive to reuse graywater and water conservation methods in Georgia due to the frequency of droughts. As discussed by Stooksbury (2003) Georgia experiences a drought of two or more years on average once in 25 years. Recently, the most severe drought in the region occurred during 2007 – 2009. Level 4 water restrictions were imposed for the northern third of Georgia, which eliminates virtually all outdoor water applications (Campana et al., 2012). Therefore, water conservation depends on water supply. If surplus water supplies are available graywater is not encouraged. If water supplies are limited, conservation and graywater receive a favorable review.

Similar to other regions, the highest priority with reusing graywater was found to be protecting public health (6 votes) versus the environment (3 votes) and water law (1 vote). One issue with permitting systems is the proper maintenance and inspection of systems to ensure proper operation. Establishing such a regulation requires excess resources that many state agencies cannot offer. Even though graywater may be able to reduce freshwater demands, the excess resources required deters from widespread application. Furthermore, there has been a lack of clarity in permit and regulation requirements between state and local jurisdictions. While state regulations may support graywater use, many local authorities may not. This confusion can significantly deter users from adopting graywater reuse.

4.5.3 The West

Water reuse, conservation, and awareness are critical in the west's urban water management scheme due to the reliability of natural water resources. The only western state that does not allow graywater reuse is Colorado. However, both Colorado entities interviewed during this project support graywater reuse, but there a lack of legislative support hindering graywater regulations. Another interesting note on western graywater regulations is the recent adoption of graywater legislation from Hawaii, Idaho, Montana, Oregon, Utah and Washington since 2008. The processes adopted for regulating, monitoring and permitting graywater reuse is substantially different and specific to each state. However, all regulations in the West have different requirements based on system size and end use. For example, higher risk scenarios such as commercial scale or toilet flushing require permits and regular maintenance. Low risk scenarios, such as residential irrigation, are typically approved if system owners adhere to the BMPs adopted by each state.

The most effective experiences with state graywater regulations has been implementing graywater use for residential irrigation (drip or subsurface). The physical barrier between human exposure and graywater reduces the exposure and does not require systems to be strictly monitored. This is also confirmed because not a single public health complaint has been filed due to the use of graywater. Therefore, it seems that low risk scenarios do not need to be strictly regulated. If residents adhere to the BMPs that follow the safe operation of graywater, there is a minimal threat to residential irrigation applications. However, the area that needs improvement in graywater regulations is addressing large scale and indoor uses of graywater. The current regulations are too strict and deter users from pursuing these systems. This is due to the lack of research from these specific areas and the high risk, high exposure scenarios. To mitigate any potential health risk regulators have adopted strict regulations.

4.6 Discussion

The need for graywater regulations is dependent on how reliable municipal water supplies are. For example in regions that have adopted reasonable graywater regulations, are in the arid regions of the country (western and southeast United States). In states that see the need for water reuse, BMPs have been found to effectively and safely regulate graywater systems compared to permits with strict water quality requirements for residential irrigation systems. For commercial/large scale and indoor applications of graywater, strict regulations are required for proper design, maintenance and operation of graywater systems.

Since there are minimal public health threats to reusing graywater for residential irrigation, instead of requiring strict regulation, providing educational resources and BMPs may be the more effective route. Prior to 2001, Arizona Department of Environmental Quality (ADEQ) required permits and a fee for all residential irrigation graywater systems. After nearly a decade of permitting graywater systems, the ADEQ issued two permits. However, a survey conducted by the Water Conservation Alliance of Southern Arizona estimated that 200,000 – 300,000 homeowners were using graywater systems; illegally without an approved permit. After 2001, ADEQ reexamined the graywater regulations and adopted the permit-by-rule approach, meaning if a homeowner followed the BMPs, graywater systems could be used without a formal permit. Since the strict permitting requirements clearly were a failure, the ADEQ invested in educating and prescribing safe uses of graywater. While this specific approach has raised some questions about the safety from county health departments, those interviewed in ADEQ felt that if a health hazard did exist, evidence would have been prevalent long before due to the 200,000 unpermitted systems.

Surveyors provided information on improvements needed for implementation of effective graywater reuse regulations. These include:

- Define a clear set of regulations that both promote the use of graywater and BMPs
- Adopt a plumbing code that promotes and supports graywater
- Provide educational materials to the public
- Establish community partnerships to ensure graywater systems are properly designed

In Addition, several knowledge gaps were identified that if answered would enable states to develop regulations which promote the safe reuse of graywater:

- Perform more pilot studies to broaden depth of knowledge
- Further study the risks associated with graywater (toilet flushing and commercial systems)
- Improve technology to allow cheaper options to treat and disperse graywater
- Understand and document technologies available to implement graywater into a variety of sites.

4.7 Conclusion

Graywater regulations can be summarized into three different categories: tiered, non-tiered, and residential irrigation. The tiered regulations are based on the amount of graywater reused. For example, as more flow is used the regulatory requirements become stricter. On the contrary, non-tiered graywater regulations only address the differences between toilet flushing and irrigation requirements. Because there are so many differences in graywater regulations, a survey was conducted to examine experiences, views and perceptions on graywater and graywater regulations. Based on the conducted survey, the two most important results are: 1) All states feel public health is the most important aspect of a graywater regulation, and 2) There has not been a single reported incident of sickness associated with graywater reuse. If any future survey based research is done, a follow up questions that could be added to this survey could be:

- Do you feel your regulations adequately address toilet flushing applications?
- If your state does allow graywater reuse for toilet flushing and provides water quality standards for toilet flush water, what were the limits for indicator organisms based on (Select one: science, observation of another regulation, based on reclaimed water, based on contact water regulations, or other)?

In conclusion, the difference in graywater regulations has left many authorities confused on a specific direction to follow for graywater regulations. For residential applications, graywater regulations do not require a strict permitting process or water quality requirements. Instead regulations should aim to identify BMPs, similar to Arizona, that protect human exposure and prevent environmental degradation. Once graywater is exposed to high risk, high exposure categories, regulations need to address regulations differently. However, systems that meet the water quality requirements should be clearly identified to the general public. Similar to Australia's method of listing the approved GTS's, states need to link available technologies to the high exposure regulations. One example of this particular application would be to adopt a third party testing facility such as the National Sanitation Foundation or supply systems that meet the standards for the International Plumbing Code. This would allow users to clearly identify what systems are available for what level of graywater they want to pursue.

CHAPTER 5 SUMMARY OF GRAYWATER TOOL

Based on the information collected on treatment and regulations, a tool was constructed in Microsoft Access 2010 and is compatible with other versions of Microsoft Access. The tool provides a single location for the abundance of information on graywater regulations and treatment technologies collected. As discussed by King (2005), a survey evaluated one of the barriers associated with implementing graywater systems in Australia is the abundance of information on treatment systems. Additionally, it was found that the information available must be readily available so all residents can quickly and easily gain information on the systems that are available. The goal of the graywater tool is to mitigate these issues by providing a single location for graywater regulations and treatment systems. The graywater tool was included in the deliverable for WateReuse Project 10-02 and can be obtained through the WateReuse Research Foundation.

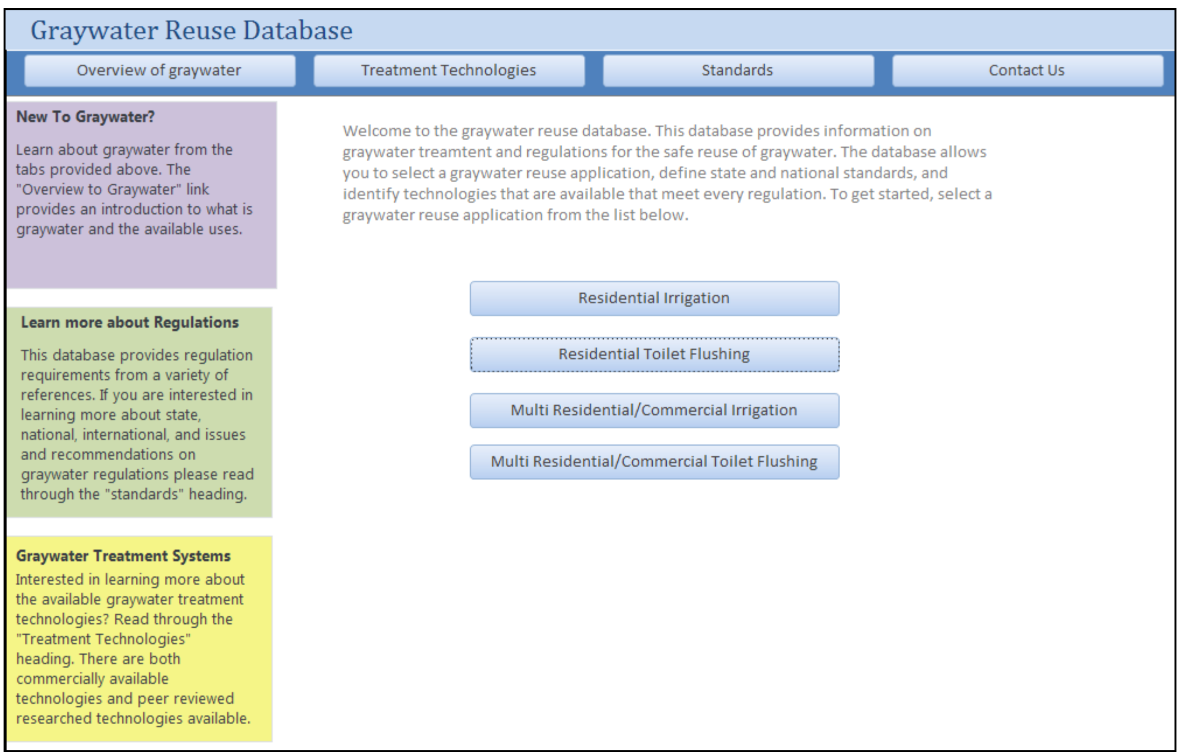

Figure 5.1 Graphical user interface of graywater tool

The graphical user interface (GUI) as displayed in Figure 5.1 provides users with the information collected for this project including an overview of graywater, the available treatment technologies and experiences from a variety of state, national and international regulations. The overview of graywater tab allows users to learn more about the characteristics of graywater such as quality, quantity and typical reuse applications. Secondly, users can browse through the available treatment technologies to learn what types of systems are available for residential irrigation, commercial irrigation, residential toilet flushing and commercial toilet flushing. Finally, users can learn about the variety of graywater regulations adopted from state, national and international experiences. This particular source would be useful for a regulator looking to adopt new graywater regulations and wanting to learn more about the variety of regulations adopted.

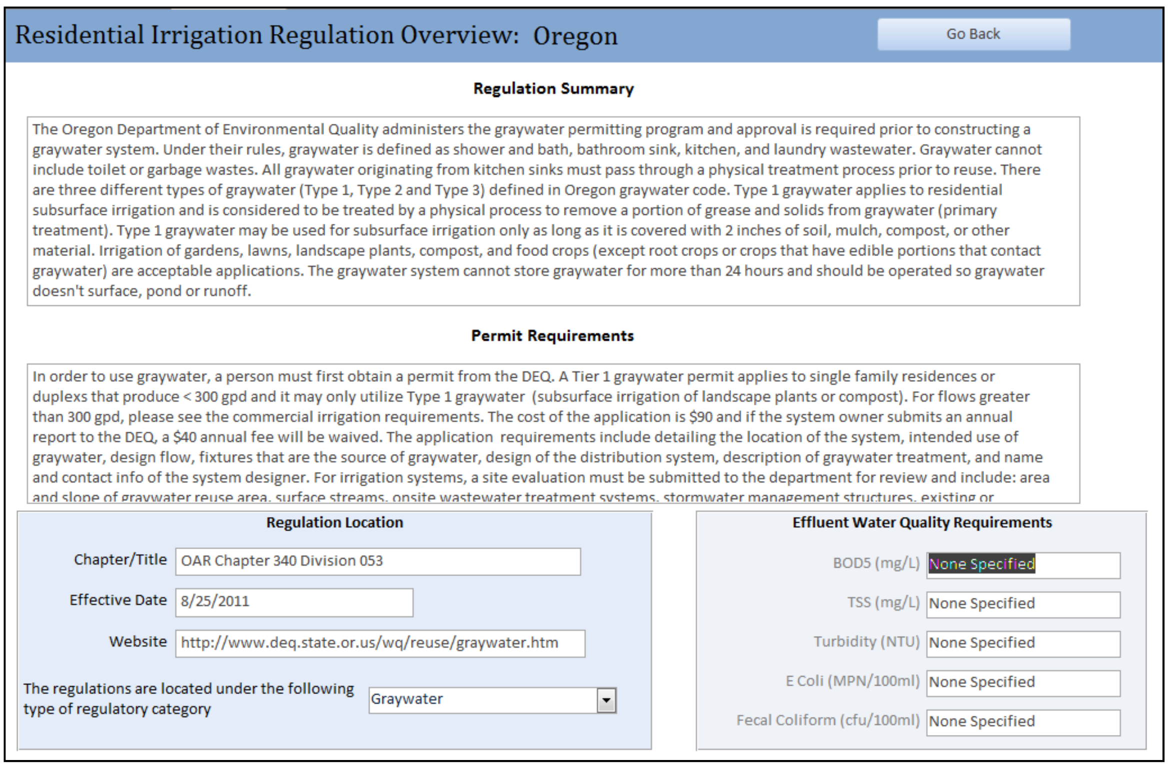

Figure 5.2 Graywater tool output for residential irrigation regulation summary

The main function of the database allows users to select an end application of graywater and a regulation of interest. Based on the user's selection, the graywater tool automatically displays information collected on permit requirements, regulation summary, website references and water quality requirements (Figure 5.2).

If the user is interested in pursuing a graywater system, a list of available systems is provided that meet the water quality requirements for the particular regulation selected. As displayed in Figure 5.3, the user can compare and contrast graywater systems to identify a system of interest. For residential applications, graywater systems are divided among diversion devices and treatment systems. If there are no water quality requirements, a diversion device is the preferred method of use because the cost to construct and maintain the system is significantly lower compared to a treatment system.

Once the user finds a system they are interested in, they can select that system to learn more about the treatment process, maintenance requirements and the testimonials compiled from the commercial manufacturer survey. Additionally, the water quality the system achieves is provided. However, this information isn't necessary because the system already meets the water quality requirements for the regulation of interest. For a more detailed walkthrough of the tool reference WateReuse Project 10-02.

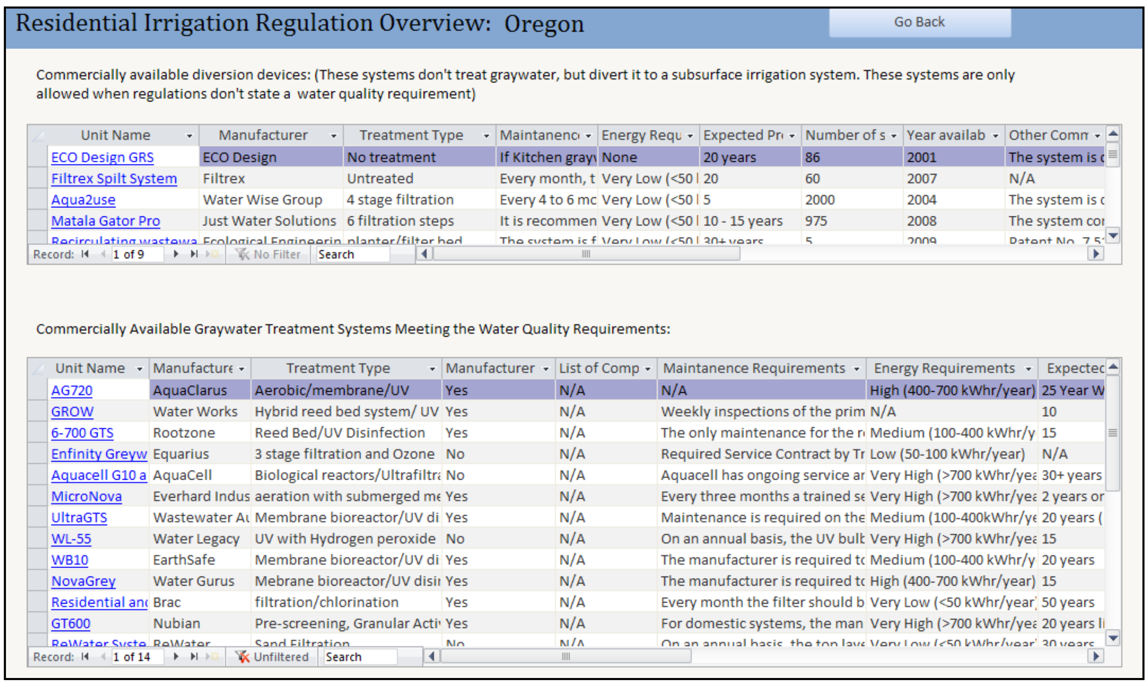

Figure 5.3 List of acceptable graywater systems meeting water quality requirements

CHAPTER 6 SUMMARY AND CONCLUSIONS

The reuse of graywater has the potential to significantly reduce demands on natural water systems. However, due to the perspectives on public health and environmental issues, regulatory barriers have slowed the process of implementing residential and commercial graywater systems. Additionally, views on water reuse vary depending on geographic location. For example, in water rich states, graywater is viewed as an unnecessary resource that doesn't need to be utilized. Therefore, the regulations reflect this perspective by requiring strict water quality and permitting requirements; or not permitting graywater use. In contrast, arid and semi-arid states with dwindling natural water supplies have researched, piloted and promoted water saving practices into a variety of applications, such as reusing graywater.

Due to the variation of graywater regulations, a survey was constructed to identify the issues associated with reusing graywater. 41 city utilities and state agencies from 25 states were surveyed for this project. 24 of the surveyors were from states that allow graywater reuse and 17 were from states which don't regulate or lack a graywater regulation. The survey findings suggest that graywater support is predominantly in arid and semi-arid regions that have diminishing natural water resources. These states have implemented a BMPs and permit-by-rule program that is used for low risk, low exposure scenarios (residential subsurface irrigation). However, after graywater is used for higher risk scenarios (commercial scale or toilet flushing), regulations must be more strict to ensure systems are properly designed, maintained and operated to reduce negatives effects on public health or the environment.

Due to the low risk, low exposure scenario, and the results from this study, using graywater for residential irrigation shouldn't require a permit or strict water quality requirements. From experience, agencies have found it to be more effective promoting and educating the safe reuse of graywater to the general public opposed to enforcing a strict permitting process. States should adopt a residential irrigation regulation similar to Arizona BMP requirements. Once graywater is used for commercial applications or toilet flushing, regulations are stricter. This justifies the reasoning behind implementing a tiered approach to regulating graywater, where residential irrigation doesn't require a permit, commercial or toilet flushing applications do. However, regulations are inconsistent among states that allow graywater reuse for toilet flushing indicating a lack of guidance. It is accepted that graywater requires a form of disinfection prior to reuse for toilet flush, but it is unknown to what degree is required. Additionally, there is a lack of information on available treatment systems identified by each state. Australian states have adopted a 26 week trial period for systems designed to be reused for toilet flushing. If systems meet the water quality requirements, they are listed on the state department's website as an acceptable system. Regulators in the United States should adopt a regulation similar to Australia's to identify available systems by either adopting third party water quality requirements (International Plumbing Code or National Sanitation Foundation 350) or testing systems independently.

Regardless of graywater regulations, the treatment of graywater improves the quality of graywater making it usable for the intended applications. The variety of treatment options for graywater is just as diverse as graywater regulations. While technologies weren't thoroughly discussed in this particular report, the reader should review WateReuse project 10-02 for more details about the treatment of graywater. The available technologies reflect the regulations of graywater varying from simple diversion devices to complex biological treatment and disinfection. Diversion devices do not provide any treatment and act as a surge tank with a pump, effectively conveying graywater to a subsurface (drip or emitter) irrigation system. Biological treatment uses a form of aeration (air blowers or natural wetlands) to effectively reduce the organic concentrations in graywater. While both these technologies are applicable forms of treatment, depending on regulatory requirements, the operation, maintenance and cost is drastically different influencing the decision to implement a graywater system. Data gathered on the water quality, maintenance and system owner testimonials of commercially available graywater systems will assist regulators in understanding system differences and promoting systems.

A second product of WateReuse project 10-02 project was compounding the information collected on regulations, surveys, and treatment systems into a concise and presentable graywater tool. The primary function of this tool is to summarize state graywater regulations and reference graywater systems that effectively meet state water quality requirements. Designed in Microsoft Access, this tool reduces the confusion associated with differences in graywater regulations and provides a single location for graywater information. In addition, the tool can be used as a reference for regulators looking for guidance in implementing graywater regulations.

In conclusion, the graywater tool can be a useful resource for regulators and agencies interested in developing graywater regulations that links available graywater systems to current regulations. Information compiled on the public health and environmental issues associated with graywater use and how regulations aim to mitigate these issues can assist regulators in determining successful regulations to adopt and promote. This tool begins to address the need for one location of regulations to obtain information on graywater reuse that is reliable. National graywater regulations seem to be implausible due to the variety of regional views and specific issues that must be addressed by each state. However, providing a single location for graywater information where states can obtain a foundation of graywater regulations would help promote a consistent approach to regulating graywater that addresses the variety of issues. Instead of forcing states to research and adopt regulations on their own, there needs to be a uniform approach to regulating graywater. This would be the first step to an organized and consistent regulation.

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APPENDIX A

Survey for Utilities and State Agencies

Graywater use Allowed:

1. What are the current graywater reuse standards and regulations? Who is the regulating authority?

2. How does your state define graywater? What is your opinion on kitchen wastewater as a source of graywater?

3. Describe how your state permits, approves, and prohibits the operation of private and public graywater systems.

4. Describe the process for monitoring private and commercial graywater systems after they have been installed. Please indicate the frequency and scope of monitoring efforts

5. What is your opinion on your state's graywater regulation?

6. What works well with your graywater regulation from an environmental and public health perspective?

7. What could be done to make the graywater regulation work better?

8. What types of technologies/systems is the general public using to treat and use graywater?

9. Does your state's regulatory framework and adopted standards encourage or discourage graywater use?

10. What is the department's view on graywater? (please check one and comment)

The department supports graywater use	
The department is neutral to graywater use	
The department is opposed to graywater use	

Comments:

11. What are the issues associated with developing regulations which enable the safe use of graywater (please prioritize 1-6, with 1 being the highest)?

	Priority
Public Health	
Environment	
Water Conservation	
Permitting/Regulation	
Water Law	
Inspection/maintenance	
Other	

Comments:

12. What are the issues associated with a graywater use regulation (Please prioritize 1-5, with 1 being the highest)?

	Priority
Unpermitted systems	
Out of compliance with code	
Enforcement	
Legal injury to persons off property	
Lack of resources/manpower	
Other	

Comments:

13. Have there been any public complaints on graywater systems that have been filed (place x by appropriate answer)? If so, please describe the complaint (nature of complaint, system size, commercial/household system, etc.)

No complaints	
A few complaints	
A moderate amount of complaints	
A lot of complaints	

Comments:

5a. what is the number of reported environmental complaints

0-10	
10-100	
100-1000	
More than 1000	

5b. what is the number of reported health complaints (sicknesses)

0-10	
10-100	
100-1000	
More than 1000	

14. Are there cases that exist where graywater systems have been deemed to be out of compliance with state code? If so, how prevalent is this and how were they dealt with?

Graywater use Not Allowed:

1. Under what standard/code is graywater currently regulated (for both single household and commercial/multi residential facilities)?

2. What is the department's view on graywater? (please check one and comment)

The department supports graywater use	
The department is neutral to graywater use	
The department is opposed to graywater use	

Comments:

3. What are the issues associated with developing regulations which enable the safe use of graywater (please prioritize 1-6, with 1 being the highest)?

	Priority
Public Health	
Environment	
Water Conservation	
Permitting/Regulation	
Water Law	
Inspection/maintenance	
Other	

Comments:

4. What are the issues associated with implementing a graywater use regulation (Please prioritize 1-5, with 1 being the highest)?

	Priority
Unpermitted systems	
Out of compliance with code	
Enforcement	
Legal injury to persons off property	
Lack of resources/manpower	
Other	

Comments:

5. What are your views on the health risks' associated with graywater use?

6. What are your views on the environmental risks' associated with graywater use?

7. What steps need to occur in order to make graywater use legal in your state?