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Perception and use of graywater in Berkeley, California

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PERCEPTION AND USE OF GRAYWATER IN BERKELEY, CALIFORNIA

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ABSTRACT

PERCEPTION AND USE OF GRAYWATER IN BERKELEY, CALIFORNIA

by Chung M. Khong

Graywater is untreated wastewater that has not come into contact with human and animal waste. The main sources of residential graywater are the bathroom tub, bathroom sink, shower, and clothes washer. This research project investigated graywater use in Berkeley, California. Its main objectives were as follows: (1) to estimate the level and type of residential graywater use, (2) to identify socio-demographic factors associated with graywater use, and (3) to gauge resident knowledge and awareness of the California's graywater regulation in Appendix G of Title 24, Part 5. The primary method of data collection was a mail survey sent to 800 owners of randomly selected single-family homes. Twenty-nine percent of respondents reported that they were either using graywater or have used it in the past, which is significantly higher than previous studies have indicated. Results of the survey also indicate that the main sources of graywater were bathroom tubs, bathroom sinks, showers, and the kitchen sink. The primary application of graywater was landscape irrigation. Lower levels of income and having a bachelor's degree were the demographic variables associated with increased probability of graywater use. Approximately 60% of respondents said they were interested in replumbing their home for graywater use, but 75% of those surveyed knew nothing about state regulations. These results demonstrate that homeowners have a strong interest in using graywater but lack the knowledge to act on it. Additional survey and face-to-face interview data demonstrate that a local non-governmental organization significantly influences resident graywater use and perception at the municipal level. Based on the study's findings, California water policy makers are encouraged to consider revising Appendix G of Title 24, Part 5--with the input of various stakeholders--to concurrently address resident interest, public health concerns, and the statewide water shortage.

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Only when all contribute their firewood can they build up a strong fire.
- Chinese Proverb

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INTRODUCTION AND PROBLEM STATEMENT

Halfway though 2007, California was marked by record low rainfall and correspondingly lower than normal snowpack levels in the Sierra Nevada. This led to lower than normal levels in reservoirs statewide. In late 2007, the California Department of Water Resources (DWR) diverted water from the Sacramento-San Joaquin Delta in an act to preserve the Delta smelt, an endangered fish in California (DWR, 2008). Since the beginning of 2008, there has been insufficient rainfall to replenish the reservoirs statewide (DWR, n.d.). In February of 2009, the water content in the Sierra snowpack was 61% of normal, leading to a third consecutive dry year in California (DWR, 2009).

As a response to the mounting concern over the current water resource challenge, some California public utilities, such as Santa Clara Valley Water District, are asking for a mandatory 10-15% reduction in water usage ("District," 2009). Counties statewide, such as Sonoma County, are seeking even more drastic measures by asking for a mandatory 30-50% reduction through ordinances (Sonoma County Water Agency, 2009). Unfortunately, water shortage issues are not confined to California.

According to the U.S. Department of the Interior (DOI) and the California Department of Water Resources (DWR), the states west of the 100th meridian will experience a great shortage of fresh water by the year 2025. During 2002, rainfall in the Colorado River basin was the lowest in recorded history; the water level in the Rio Grande River in New Mexico was at 13% of normal; and the Elephant Butte Reservoir, also in New Mexico, was at 19% of its maximum capacity (DOI, 2003).

To further exacerbate the current water supply crisis in California and in states west of the 100^{th} meridian, the Bureau of Reclamation under the DOI generated a model that predicts states in the West that will experience potential shortages in water supply of varying degrees by 2025 (see Figure 1). This potential in water supply shortage is, according to the model, affected by the combination of three key factors: hydrologic influences, environmental issues, and population growth trends (DOI, 2005). The intensity of the water supply crisis depends on the interaction of these three key factors.

This model's predictions are consistent with what is currently happening in California as the state enters its third year of drought (DWR, 2009). In the Central Valley, farmers might be allocated less water for their agricultural needs (MacDonald, 2009). The model also shows stresses on two major water systems, the State Water Project and Central Valley Project. These supply all of California with potable drinking water from different watersheds in Northern California (Freeman, 2008). According to this model, the areas around San Francisco, and in particular the Central Valley, which are shaded brown and red, respectively, will experience a water crisis potential of moderate-to-severe levels by 2025 (see Figure 1).

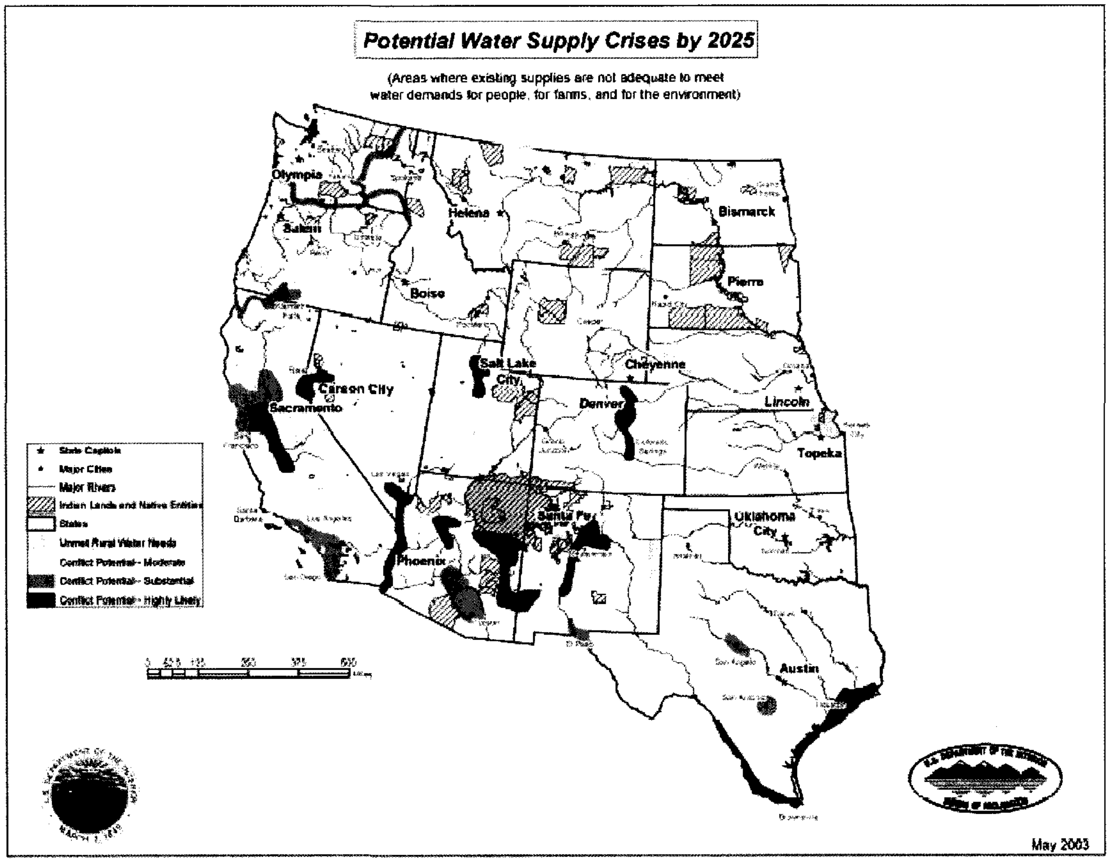

Figure 1. Map of potential water supply crisis in western U.S. by 2025.
(Source: US Bureau of Reclamation).

Solutions

Solutions for achieving water conservation currently focus on two major renewable sources, recycled and desalinated waters (see Table 1), among other more traditional techniques such as using less water when bathing. These two renewable resources are of great interest to water professionals because of the amount of potable water saved along with the amount of energy conserved through the water-treatment process.

Table 1

Comparison of water and energy savings from recycled and desalinated waters with graywater.

Savings	Potable Water Savings (acre feet)	Energy Savings (million kwh)
Renewable Resources		
Recycled Water [a]	52,233	212
Desalination (ocean and brackish water) [b]	500,000	268
Graywater	?	?

[a] Richardson, Ashktorab, John, and Zhu, 2006.
[b] BenJemaa and Karajeh, 2007.

Desalination technology is being researched as one of the many ways to augment our drinking water supply, using seawater as its source. It is not the only technology available to address water-conservation issues. Recycled water, which has been in existence in California since the late 1800s and originates from wastewater (CDPH, 2001), has been used throughout the centuries for irrigating landscape, agriculture, and recently in industrial applications (DWR, 2004). The use of recycled water to irrigate landscape as well as in certain agricultural uses and in the industrial sector, has made it possible to divert much of the potable water supply in California for drinking and other related needs and activities (DWR, 2004).

Graywater

There has been considerable research performed on recycled and desalinated waters as renewable resources available to address shortages in water supply (US EPA, 2004). However, of the renewable resources mentioned thus far, there has not been comparable research for graywater (see Table 1). Graywater is untreated wastewater that has not come into contact with human and/or animal waste. The sources of graywater are the bathroom tub, bathroom sink, shower, and clothes washer (CDPH, 2001). The kitchen sink could be a source of graywater, but due to contamination from oils, greases, and food particles and its low (5%) contribution to the total waste stream for a household, it is not recommended as a source (Christova-Boal, Lechte, and Shipton, 1995).

Graywater constitutes approximately 50% of the total volume of wastewater discharged for a household (Roesner, Qian, Criswell, Stromberger, and Klein, 2006). Reusing graywater has been shown to increase the efficient use of water in the home and minimizes the reliance on municipal water, conserving potable water (Christova-Boal et al., 1995). Graywater use in an average household can lead to an estimated 18-29% in water savings, according to Christova-Boal et al. (1995). In a study in 1999, conducted by the Soap and Detergent Association (SDA), it was reported that 7% of households in the U.S. used graywater (Roesner et al., 2006).

Before going further into a discussion about graywater use and its benefits, its chemical and microbial composition must be understood. The quality of graywater varies throughout the world, but its essence remains relatively consistent. Graywater is more polluted than conventional waters, like reservoirs or lakes. Depending on the source, graywater can vary in organic and inorganic contaminants as well as in the concentration of total coliform and *E. coli* bacteria (see Table 2).

For example, the concentration of total coliform bacteria is higher in the hand washing basin because that is the first place where soiled upper extremities are typically cleaned. *E. coli* concentrations are higher in the shower and bath areas because that is where bodily areas with fecal contamination are directly washed. Total coliform bacteria and *E. coli*, however, are not the only microorganisms of concern in graywater.

Table 2

Water quality parameters for graywater in comparison to raw and treated waters for potable uses.

		Graywater[b]			RWTP Treated[a]	RWTP Raw[a]
Water Quality Parameter	Units	Shower	Bath	Hand Basin	Potable Water	Source Water
BOD	mg/l	146	129	155	NA	NA
COD	mg/l	420	367	587	NA	NA
TOC	mg/l	65.3	59.8	99	1.7	2.7
Turbidity	NTU	84.8	59.8	164	0.07	3.74
SS	mg/l	89	58	153	<0.01	NA
TC	CFU/100 ml	6800	6350	9420	ND	336
E. coli	CFU/100 ml	1490	82.7	10	ND	2
PO_4	mg/l	0.3	0.4	0.4	1.19	0.27
NH_3	mg/l	NA	NA	NA	0.11	<0.05
NO_3	mg/l	NA	NA	NA	ND	ND
pH		7.52	7.57	7.32	7.6	8.3

NA = not available
ND = not detected
BOD = biological oxygen demand
COD = chemical oxygen demand
NTU = nephelometry turbidity unit
CFU = colony forming unit
TOC = total organic carbon
SS = settleable solids
TC = total coliform
SCVWD = Santa Clara Valley Water District
RWTP = Rinconada Water Treatment Plant

[a.] Potable and source water quality data from SCVWD monthly report for RWTP influent and effluent during October 2008.

[b.] Graywater data from Jefferson et al., 2004.

In 1998, the Water Conservation Alliance of Southern Arizona (CASA) conducted a residential graywater study in which it analyzed graywater and graywater-irrigated soils for *E. coli*, fecal streptococci, fecal coliforms, coliphages, and protozoan parasites. Of these microorganisms, only fecal coliforms, *E. coli*, and fecal streptococci were detected in the residential graywater and graywater-irrigated soils (Little et al., 2000). Fecal coliform and *E. coli* concentrations were higher in graywater from households with children than those without (Little et al., 2000; Roesner et al., 2006).

The concentration of fecal coliform found in graywater exceeds regulatory standards for discharge of wastewater and for bodily contact (Roesner et al., 2006). Graywater, however, is quite different bacteriologically from its close analog, blackwater. Blackwater, the source for recycled water, is wastewater that comes from kitchen sinks, toilets and dishwashers. It poses a greater health hazard because of the presence of harmful bacteria, viruses, and pathogens (ADEQ, 2004).

Graywater has been widely used as a resource in the United States to address water conservation issues, though most of its use in the past was not regulated (Christova-Boal et al., 1995). It is a resource that has been in use since the 1920s in the United States and in countries around the world such as Spain, Australia, Germany, and Japan (Roesner et al., 2006; Christova-Boal et al., 1995). Only a few states, including New Mexico, Arizona, and Texas, have considered and use raw graywater in landscape irrigation (Roesner et al., 2006). Internationally, only a few countries such as Germany (Nolde, 1999), Spain (March et al., 2003), and Australia (Christova-Boal et al., 1995) have tried to use it in toilet flushing. Other uses for graywater in foreign countries include landscaping and filling fountains (Christova-Boal et al., 1995).

In California, a pilot study is currently being developed by the Contra Costa Water District to test a graywater use system called Aqus (see Figure 2) in a few residential homes (C. Dundon, e-mail communication through NGO, January 19, 2009). This particular system, developed by WaterSaver Technologies, collects graywater from the bathroom sink, filters it, disinfects it, and then pumps it into the toilet tank for flushing (Ballanco, 2007). The Aqus uses graywater to flush the toilet while maintaining proper sanitation and cleanliness, priorities in any water reuse system (Ballanco, 2007).

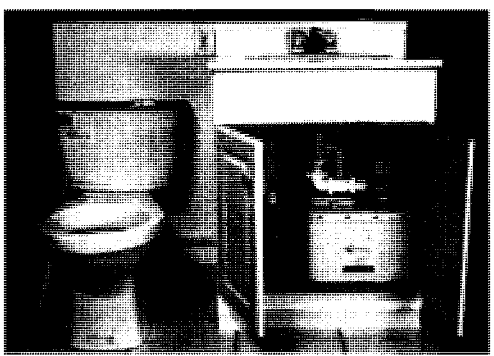

Figure 2. The Aqus, a graywater recycling system.
(Source: www.vivavi.com). Reprinted with permission from WaterSaver Technologies
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The survey study of residential graywater use in Berkeley, CA, discussed here, did not analyze the quality of graywater generated on-site, but rather the frequency of graywater use in the single-family residence, sources and areas of use, its perception based on use, and related regulations. Findings from this study indicate the following: (1) Residential graywater use was at 29% for current and past use, (2) Graywater drawn from the bathroom tub, bathroom sink, shower, and kitchen sink was used mainly for irrigating landscape, (3) Socio-demographic factors associated with graywater use were income and education, and (4) Survey respondents had a positive perception of graywater and its potential in water conservation.

With the use of graywater, its role in water conservation, and potential risks in mind, the following literature review examines case studies of residential graywater use, related research on socio-demographic factors associated with residential use, the perception of graywater use, and regulations guiding its use.

LITERATURE REVIEW

Graywater use is proliferating in countries around the world, along with the use of other renewable water resources, in light of freshwater shortages and concerns stemming from global warming. Studies on this particular type of water reuse have mostly been concentrated in the residential area since it has been shown to potentially reduce the current demand on the municipal water supply by 18% (Christova-Boal et al., 1995). Residential graywater use is associated with socio-demographic factors, like income, while the level of graywater use is associated with how it is perceived. Its perception, in turn, is associated with regulations guiding its use. The following literature review focuses on case studies showing the level of residential graywater use, socio-demographic factors associated with its use, perceptions of graywater use, and related regulations guiding its use.

Residential Graywater Use

A case study that focused on the prevalence of residential graywater use and some of its physicochemical and microbial characteristics came from Arizona, one of the most arid states in the United States. The Water Conservation Alliance of Southern Arizona (CASA) led the residential graywater study with cooperation from the Arizona Department of Water Resources, the Arizona Department of Environmental Quality (ADEQ), and the Pima County Department of Environmental Quality. The goals of the study were to determine if health risks and graywater use were positively correlated and whether or not the graywater permitting process could be made more accommodating (Gelt, Henderson, Seasholes, Tellman, and Woodard, 1999). The study looked at the following: (1) the number of households using a portion of the graywater that they generated, (2) the quality of the graywater generated, and (3) how graywater affected the soil that received it (Little et al., 2000).

Frequency of residential graywater use was determined by mailing surveys to single family residences in the service areas of six water providers (Little et al., 2000). Homes in two other water service providers were also surveyed, but the focus was on the other six providers due to the insignificant number of single-family households in those two service areas. The recipients of the surveys were identified from the October 1999 Pima County ARCVIEW database. Survey recipients were randomly chosen from a pool of residents living within the boundaries of the water service providers. Results from survey questions were collected, analyzed and posted without much statistical analysis (Little et al., 2000).

Health risks of using graywater and its impact on soil were determined by conducting water sampling and analysis from residences that participated in the survey study (Little et al., 2000). Samples were collected following the Field Manual for Water Quality Sampling, published by ADEQ and the University of Arizona's Water Resources Research Center. The various microbiological parameters that were analyzed were done in accordance with either the Standard Methods for the Examination of Water and Wastewater or individual techniques from commercial labs and researchers. The raw, numerical data from these analyses were statistically analyzed using ANOVA with SYSTAT (Little et al., 2000).

The results of the graywater use survey showed that out of the eight water service providers surveyed, residences in the service area of four providers (Flowing Wells, Marana, Ray, and Tucson Water) were showing graywater use rates between 13 and 16%. The highest graywater use rate came from residences serviced by Avra Co-op with a 25% use rate; the lowest rate at 1.5% came from Green Valley. Since fewer surveys were mailed to Avra Co-op, study researchers determined the high graywater use percentage was statistically insignificant (Little et al., 2000). Graywater use for this study was weighted to 13% for the population of Tucson (Little et al., 2000), with most systems being unpermitted.

Little et al. (2000) determined that residents who belonged to lower income levels, owned older homes low in value, owned manufactured homes, and had septic tanks on their property were more likely to use graywater, according to the survey results. Three of the four service areas, which exhibited a statistically higher percentage of graywater use, had relatively lower household incomes. Additionally, these areas had a high occurrence of septic tanks. In terms of the quality of graywater used by residents in the survey study, only fecal coliforms, *E. coli*, and fecal streptococci were detected in the residential graywater and graywater-irrigated soils (Little et al., 2000).

A majority of the residents from the survey (over 90%) were not using graywater because they did not know how to use it. Around 30% of the total responses given for not using graywater related to the lack of knowledge of how to use it and the lack of assistance and information about its use (Little et al., 2000). 20% of the total responses given for not using graywater related to lack of time and a lack of an economic incentive. Impracticality and inconvenience accounted for 19% of responses. Public health and environmental impacts accounted for 15% of responses. Around 7% of those surveyed mentioned hassles with permitting and other legalities as their reasons for not using graywater. Reasons grouped in "other" accounted for the remaining 10% of responses (Little et al., 2000).

Based on the observations gathered from residents on graywater perception and use, Little et al. (2000) concluded that if legal barriers are lowered and public education and incentives are given and enhanced, [legal] graywater use "might increase considerably" (Little et al., 2000, p.11). Due to the high rate of illegal graywater usage observed from the survey of the greater Tucson area, the Arizona Department of Environmental Quality revised its graywater regulations (Little et al., 2008). This study, by Water CASA, is the only study on graywater use in the United States that related perception of graywater use to socio-demographic factors.

The residential graywater study by Water CASA study looked at unpermitted, residential systems. Whitney et al. (1999) studied the feasibility of residential graywater use for permitted systems in California. In this particular study, which involved three homes in three different cities and was conducted over a two year period, Whitney et al. (1999) researched the technological and economical feasibility of graywater based irrigation systems that were permitted by respective local agencies. The graywater studies were carried out in the cities of Santa Barbara, Danville, and Castro Valley under the direction of technical staff from the Department of Water Resources (DWR).

There were interesting results from this study on residential graywater application. Graywater used in landscape irrigation did not have any negative impact on plant and soil conditions. The graywater systems also appeared to require little maintenance. However, the graywater systems were more cost effective when existing, large family dwellings were retrofitted. The dwellings had to be single story with a raised foundation; the presence of a sloped foundation was also helpful in the delivery of the graywater to the landscape. The raised foundation eliminated the need for a pump that would have otherwise increased the system cost (Whitney et al., 1999). These factors limit the use of graywater systems for only a fraction of the population in California.

The permitting process for installing a graywater system was noted as being "troublesome" for the permitting agency because of the concern about proper venting in the graywater system. The authors, however, warned that the study should "not be considered a comprehensive, definitive report on graywater, either extolling or discouraging its use" (Whitney et al., 1999, p. 1).

It seems that, from the study by Whitney et al. (1999), the two major obstacles to having a graywater system in a home were related to site conditions and policy. With these specific and seemingly restrictive requirements to its use, graywater still appears to be a feasible solution to water conservation in residential areas.

Graywater Use and Sociodemographic Factors

There are not very many case studies or much research relating graywater use with socio-demographic factors, other than Little et al. (2000) and the current survey study. There are, however, several other sociological studies that determined correlations between environmental concern and various socio-demographic variables, similar to those analyzed in the current survey study of the perception of graywater use in Berkeley, CA.

Income

Very few studies looked at whether socio-demographic factors, like income, are associated with graywater use. A majority of studies were focused on socio-demographic factors associated with environmental concern. Though these studies focused on this general topic, the observations made can be applied to residential graywater use because it is a type of an activity that shows environmental concern by alleviating stress on potable water supplies, a limited natural resource.

Income has limited, significant effects on environmental concern, as observed by Guagnano and Markee (1995). In their survey of 4,600 households in 19 metropolitan areas in the United States, Guagnano and Markee (1995) tested a set of socio-demographic variables against four measures of environmental concern for correlation: trust, responsibility, complexity, and economic trade-off. The relationships between these measures of environmental concern and demographic variables were measured while looking at their variations in different geographical regions across the United States.

Income was shown to have a significant effect on two of the four measures, namely the responsibility of business and government to protect the environment and the complexity of actions needed to solve environmental issues (Guagnano and Markee, 1995). Residents from lower income levels (less than $15,000 a year) were more likely to place the responsibility for protecting the environment on government and business than those with higher incomes ($60,000 or more). Residents from lower income levels (less than $15,000 a year) were also more likely to report the complexity of issues surrounding the environment than those in other income levels (Guagnano and Markee, 1995).

Income is positively correlated to what Klineberg, McKeever, and Rothenbach (1998, p.748) termed as "pro-environmental behaviors." This study surveyed 1,000 adults in Texas over a four-year period. They determined that people with higher household incomes were more likely to donate their money to environmental organizations and were more likely to participate in recycling materials, and avoid buying items that are detrimental to the environment (Klineberg et al., 1998).

Graywater studies observing socio-demographic factors associated with its use are few and far in between. While not focusing on socio-demographic factors linked with residential graywater use, Little et al. (2000) observed that residents with lower household incomes, relative to those with higher incomes, were using more graywater. Jeffrey et al. (2002) found that, after researching the public attitudes of in-home water recycling in the United Kingdom, there was no significant change in the public support of graywater use across the following socio-demographic groups: age, gender, and socio-economic.

Education

There are very few studies linking graywater specifically with education. A majority of studies performed were focused on socio-demographic factors associated with environmentally conscious attitudes. In terms of environmental concern, graywater use can be classified as a type of behavior that is environmentally conscious because it seeks to conserve a precious and limited natural resource.

According to Schmidt (2007), students who enrolled in an introductory class on environmental issues (ENV 201) had more "pro-environmental" attitudes than those who did not attend the course. In addition, the students who attended the course reported a heightened sense of environmental awareness and exhibited more environmentally conscious behaviors. The results of the study also showed a positive trend in the association between pro-environmental attitudes and environmental conscious behavior at the completion of the course.

For those students who did not attend the course, there was a comparatively lower level of environmental awareness. Schmidt (2007) concluded that, based on the findings, there is a great need for environmental awareness to be incorporated more frequently in the college curriculum. By following this, the environment is cared for and the livelihood of each student is enhanced.

Guagnano and Markee (1995) also observed a positive correlation between education and environmental concern, corroborating results from Schmidt (2007).

Residents with higher education levels placed less trust in government and other institutions to protect the environment, placed responsibility on themselves to protect the environment rather than on institutions, thought environmental issues were less complex to solve, and believed in lower economic trade-offs from environmental protection (Guagnano and Markee, 1995). Klineberg, McKeever, and Rothenbach (1998) also noted that people who are more educated tend to be more aware of their environment and thus more determined to act when there is a need in solving environmental issues.

Though not specifically related to the study graywater, but water reuse nonetheless, Liu (2006) observed a positive correlation between having a higher level of education and the likelihood to support water reuse in her survey study of the perception of water reuse in Santa Clara County, California. The main objective of the research by Liu (2006) was to determine the presence of any statistical relationship between the public perception of water reuse and demographic variables, i.e. age, gender, and level of education. Liu (2006) determined that there was statistical significance in the correlation between the public's concern of health risks and recycled water use.

Age

The third socio-demographic factor associated with environmental concern is age. Guagnano and Markee (1995, p. 147) noted that though most research in the field relating socio-demographic variables with environmental concern report "a negative correlation between age and environmental concern," their own research found some, though limited, support between age and environmental concern. The only measure of environmental concern that showed some effect with age was the trust in industry, business and government to protect the environment. Residents over the age of 65 years old had "significantly higher levels of trust" compared with their younger cohorts (Guagnano and Markee, 1995, p. 142).

A negative correlation between age and environmental concern was noted by Klineberg, McKeever, and Rothenbach (1998). Their goal was to determine demographic predictors of environmental concern and ways to elucidate conflicting relationships reported by previous research. Klineberg et al. (1998) determined that subjects who were younger and more educated had a deeper concern for environmental issues making them more committed to protecting the environment. This observation was reached regardless of how the dependent variable (environmental concern) was measured.

Liu (2006), however, determined that age is positively correlated with the support for water reuse in her study of the public perception of water reuse projects in Santa Clara County. It was shown that younger respondents were not more likely to support the use of recycled water than older respondents.

Perception of Residential Graywater Use

Other than the residential graywater study by Water CASA, most studies on the perception of residential graywater use were conducted overseas. Graywater use has been and still is an important renewable resource in Australia since it is "one of the world's highest water consumers per capita in the world, and approximately a quarter of [it's] surface water management areas are nearing, or have exceeded, sustainable extraction limits" (Ng, 2004, p. *i*).

Two sets of social surveys were conducted by Christova-Boal et al. (1995) regarding graywater use. The first one consisted of 300 telephone surveys randomly conducted in Melbourne, Australia. The second was a survey questionnaire sent to 990 randomly selected residences in Melton, Australia. The research objectives of the two studies were to assess the following: (1) the social perception of graywater use, (2) the likely public and environmental impacts of graywater use, and (3) the technical and economic feasibility of using graywater from the bathroom and laundry areas for irrigating gardens and flushing toilets. The social perception of graywater use from the study by Christova-Boal et al. (1995) will be focused on instead of the second and third objectives regarding the impacts of graywater and its technical and economic feasibility.

In the Melbourne survey, 40% of the residents indicated that they were interested in using graywater to water their garden, with only 11% willing to use graywater to flush their toilets. Survey respondents in Melton were more willing to use graywater in watering their gardens (85%) and in flushing toilets (64%). The results also showed that graywater use was more prevalent among home owners and retirees, people between the ages of 40 and 49, and workers in professional, managerial, and home making occupations (Christova-Boal et al., 1995). In the Melbourne study, only 7% of participants were aware of the word "greywater" and only 4% had a correct understanding of the word. There were even respondents who had experience in using graywater for irrigating gardens, but had not heard of the word "greywater" (Christova-Boal et al., 1995).

Based on these findings regarding the awareness and understanding of graywater, Christova-Boal et al. (1995) recommended that the Water Authority in Australia be invested in and be responsible for educating the community about the benefits of using graywater. The outreach was to be carried out while informing the public about potential risks involved in graywater use (Christova-Boal et al., 1995).

Jamrah et al. (n.d.) evaluated sustainable water resource management in residential homes for the Sultanate of Oman. In this study, Jamrah et al. (n.d.) analyzed the quality of graywater in 169 households (1,365 people) from various sources and conducted a survey on the perception of graywater and its various uses among household members.

Tests showed that graywater quality varied as the source varied from laundry washer to the shower to the kitchen sink. The quality of graywater was also affected by the composition of the family, for example, in the number of children, and the life style of its members. In the area concerning perception of graywater use, 82% of survey respondents approved its use for irrigating gardens, 68% approved its use for flushing toilets, and 56% indicated that they would approve graywater use for washing cars. Of the respondents who opposed using graywater, 88% opposed its use due to health risks, 53% opposed its use due to environmental impacts, and 24% opposed its use due to cost. 60% of survey respondents indicated that they were opposed the use of graywater due to religious reasons (Jamrah et al., n.d.).

Jefferson et al. (2004) found that there was a general willingness to recycle graywater in the urban setting, just as long as public health was not compromised. Jeffrey (2002) also observed that residents were more willing to use their own graywater than their neighbors'.

Liu (2006) made an observation regarding the public perception of recycled water that coincided with observations by Jamral et al. (n.d.). The public often rejected projects involving recycled water because of perceptions related to health risks due to contact (Liu, 2006). This ill perception of recycled water was due to its "unnatural" origins from wastewater and the various pathogenic organisms that it might harbor (Liu, 2006).

Graywater has been used to irrigate gardens and flush toilets, conserving water for potable uses. Its beneficial use, however, is stymied by potential health risks due to contact. Fortunately, the risks associated with graywater use are addressed and mitigated with regulations.

Graywater Regulations and Guidelines

An observation from the case study by Whitney et al. (1999) was that the permitting process for residential graywater use turned out to be "troublesome" for the permitting agencies. This particular permitting process is found in Appendix G of the California Plumbing Code (CPC), under Title 24, Part 5. Similarly, residents from the Water CASA study in Arizona cited legal and permitting issues as some reasons why graywater was not used (Little et al., 2000). However, new graywater regulations, found in Title 18 (Chapter 9, Article 7), were put into practice after results were published from the Water CASA study (Little et al., 2008). Before looking at these regulations in detail, the background of their creation must be understood.

Background behind Appendix G (Title 24, Part 5) (California Plumbing Code)

Precipitation in California has varied dramatically year to year according to a primer on California's water supply and management, published by the Legislative Analyst's Office (Freeman, 2008). During this period of dramatic fluctuations in precipitation, especially in 1977, the single driest year in California's history, there was a severe drought (DWR, n.d.; Appendix F, Question 1). During this drought, a survey reported an unspecified number of illegal graywater use systems throughout California and possibly throughout the entire United States. It was not until 1992 that a specific set of rules was created to regulate residential graywater use in California (Christova-Boal et al., 1995).

In February 1992, Assembly Bill 3518 was passed, which required a change to the California water code, allowing the use of graywater in single-family residences. In September 1992, the International Association of Plumbing and Mechanical Officials (IAPMO) created an Appendix G in the Uniform Plumbing Code (UPC) (Graywater Policy and Science Center, 2009). Appendix G from the UPC promulgates standards for graywater use in twenty-two states across the Western United States. In 1994, policy makers in California adopted Appendix J, a modified form of Appendix G from the UPC, and placed it in the CPC. Appendix J permitted the use of graywater in the residential setting, but for subsurface applications only (S. Eching, e-mail communication, July 8, 2008).

The Building Standards Commission in 1997 reformatted Appendix J and renamed it to Appendix G (Title 24, Part 5) in the CPC, the current regulations on graywater use across California. According to this Appendix G in the CPC, graywater can be used in industrial, commercial and multiunit dwelling construction settings, not to mention single-family homes as well (S. Eching, e-mail communication, July 8, 2008). Appendix G (Title 24, Part 5) may be modified with the recent passage of Senate Bill 1258 (Lowenthal), which was signed by Governor Schwarzenegger on July 22, 2008 (J. Rowland, e-mail communication, December 18, 2008).

Appendix G (Title 24, Part 5) (California Plumbing Code)

Appendix G (Title 24, Part 5) lays out the requirements for how to obtain a permit in order to legally use graywater. It is divided into eleven sections with detailed requirements and specifications for how to install and use a graywater system. The interested user may apply for a sub-surface drip irrigation system, mini-leach field or "other equivalent irrigation method" approved by the Administrative Authority, a city or county agency (DWR, 1997).

If an interested graywater user applies for a sub-surface drip irrigation system, he or she would have to first submit detailed drawings of a sub-surface irrigation system, followed by a battery of tests for percolation or infiltration, soil formation, and a characterization of the graywater to be used on site. Before a system is approved, the applicant must determine how much graywater will be generated and discharged by the chosen system. The volume of graywater discharged must meet the tolerated load capacity of the soil, in the case of a sub-surface irrigation system. Once these steps are passed, the applicant can proceed to have an irrigation field constructed and system installed. Once the irrigation field is complete and sub surface system is in place, inspections and further testing are performed to ensure compliance and efficacy (DWR, 1997).

The interested applicant can also follow a more visually friendly format containing the same steps found in Appendix G (Title 24, Part 5) to obtain a permit for using graywater. These steps are outlined in a publication titled, "Using Graywater in Your Home Landscape: Graywater Guide," by the California DWR. In this publication, permit requirements, prohibitions for graywater use, especially on herb and vegetable gardens, and suitable plants for graywater are depicted with aesthetically pleasing drawings (DWR, 1995). The particular prohibition of graywater use on herb and vegetable gardens testifies to the focus of public health protection still upheld by state officials who authored Appendix G (Title 24, Part 5) in California (Carpenter, 2008).

Guidelines for the proper use of graywater are found in other states and those guidelines differ from Appendix G (Title 24, Part 5). For example, Appendix G (Title 24, Part 5) is different from Arizona's graywater code, which is found in Title 18, Chapter 9, Article 7.

Background behind Title 18 (Chapter 9, Article 7) (Arizona Graywater Rule)

Arizona is a relatively dry, inland state that is located near the 30^0 north latitude, aptly named the "arid zone" (Gelt et al., 1999). It has two main sources of water, the Central Arizona Project (CAP) and its groundwater basins. The CAP is a network of canals that carries water from the Colorado River to Phoenix and southern Arizona (Gelt et al., 1999).

Because Arizona is located in the "arid zone" and expected to have an additional 5.6 million people by 2030 (US Census Bureau, n.d.), it is experiencing stresses in water supply from the Colorado River and groundwater basins (Gelt et al., 1999; Tucson Water Department, 2008). Therefore, regulating water use is extremely important. As a result of these stresses, water conservation techniques were developed.

Graywater use in Arizona was legalized in 1992 under Appendix G of the UPC from the IAPMO (Graywater Policy and Science Center, 2009, ¶ 6; S. Eching, e-mail communication, July 8, 2008). The Water CASA study from 1998 to 2000 was carried out while Appendix G, from the UPC, in Arizona was still in effect (Little et al., 2008).

With the revelation of a "dismal compliance rate" to Appendix G from the UPC, published by Water CASA's study from 1998 to 2000, the Arizona legislature revised its residential graywater regulations in 2001 to include one "blanket permit" for every potential graywater user who meets a certain set of requirements (Graywater Policy and Science Center, 2009, ¶ 11; Arizona Administrative Register, 1999, p. 1580, part 5). These requirements are now in Title 18 (Chapter 9, Article 7).

Title 18 (Chapter 9, Article 7) (Arizona Graywater Rule)

Title 18 (Chapter 9, Article 7) describes three tiers that interested parties can follow if they want to use graywater on their residential property. The three tiers are identified by the maximum volume of graywater generated per day. They are also relatively easy to understand and follow (ADEQ, 2001).

For example, under Tier 1, if a person were to generate less than 400 gallons per day of graywater, he or she can use graywater within the prescribed guidelines for a Reclaimed Water Type 1 Permit. Under this general permit, the homeowner must use the graywater for irrigation purposes only and not for dust control, cooling, or any other water reuse. In addition, the graywater use must be restricted to the confines of the property and not be accessed by the public. Furthermore, while spray irrigation of graywater is prohibited, drip irrigation is allowed with attention to avoid excessive ponding.

In addition to these basic requirements and as a prerequisite for compliance, the residential graywater user must abide by the 13 best management practices (BMPs) outlined under the Type 1 General Use permit. A BMP, in the case of graywater use, is a practice that is carried out to mitigate the potential effects of graywater use in order to protect people and the environment.

One of the BMPs under Tier 1 is that graywater is to be used for gardening, composting, and irrigating the lawn and landscape, while keeping its use within the boundaries of the property. The most appealing parts about the Type 1 General Use Permit are the following: (1) The residential graywater user does not have to notify the Arizona Department of Environmental Quality of his or her use intentions, (2) The user does not have to apply for review or design approval, and (3) The user does not have to apply for public notice, reporting or renewal (ADEQ, 2001).

Title 18 (Chapter 9, Article 7), with its three-tier system for using residential graywater, is a more simplified set of regulations when compared with Appendix G (Title

24, Part 5). Furthermore, the relative ease of using graywater at the Tier 1 level (400 gallons or less per day), marked by following 13 BMPs and the absence of permits and notifications, makes residential water reuse economical and more appealing.

Other Related Literature

Thus far, there has not been a great deal of statistical data correlating residential graywater use to socio-demographic factors, but there are other studies mentioned which relate them to environmental concern and water reuse. In terms of public perception, graywater is perceived favorably by members of the public in regards to its various uses. However, concerns remain due to public health risks from the relatively high concentration of total coliform bacteria found in graywater. To properly guide and protect the public in the use of graywater, regulations like Appendix G (Title 24, Part 5) and Title 18 (Chapter 9, Article 7) were developed.

The study of graywater use, its relationship with socio-demographic variables, its public perception, and related use regulations are important. There are research studies in other areas of graywater use that are equally if not more important. Table 3 illustrates other studies on the water quality of graywater, the various technologies available to effectively treat graywater, and other areas where graywater use is applied. Though not comprehensive, the studies shown in Table 3 represent the potential and feasibility of graywater use.

Table 3

Related literature on graywater quality, treatment technologies, and other areas of graywater application.

Author	Date	Emphasis/Study	Findings
		Water Quality	
Casanova et al.	2001	Chemical and microbial characterization of graywater for home retrofitted with graywater recycling system.	fecal coliforms, BOD and turbidity were higer in households with two adults and one child.
Jefferson et al.	2004	Physicochemical and microbiological characterization of greywater from different household sources in Great Britain.	water quality of greywater analyzed varied significantly from different household sources (shower to hand washing basin); systems using biological processes most suitable for greywater treatment.
		Treatment Technologies	
Gerba et al.	1995	Efficiency study of different graywater treatment systems for single-family home in Arizona, United States.	treatment systems using water hyacinths, cooper ion and sand filtration more effective for GW treatment; water quality study.
Dallas et al.	2004	Treatment of graywater using an insitu wetland system in Monteverde, Costa Rica.	a low cost, insitu wetland system using local plant (*Coix lacryma-jobi*) was shown to effectively treat graywater suitable for reuse.
		Graywater Use	
Karpiscak et al.	1990	Water conservation efforts at Casa del Agua, a home retrofitted with different water conserving systems in Arizona, United States.	reliance on municipal water reduced 66% to 148 gpd; graywater reuse averaged 77 gpd (32% of total household water use); different water conserving techniques used were rainwater harvesting, graywater reuse, low flush toilets; graywater used for irrigation and toilet flushing.
March et al.	2003	Assessment of the reuse of graywater in toilet flushing for hotel in Spain.	good water quality achieved for graywater reused for toilet flushing; customers satisfied with reuse.

To date, no research has been conducted on assessing residential graywater use, its perception, and the influence that its regulatory guidelines have on both. From this review of the literature on residential graywater use, its perception, and related regulations, the focus of the research questions for the current study centered on the level of residential graywater use in a particular Californian city, the demographic variables associated with residential graywater use, the perception of graywater use, and how it is affected by Appendix G (Title 24, Part 5).

RESEARCH QUESTIONS

Based on the review of available literature on residential graywater use, its perception, and the related regulations, the following research questions on graywater use, perception, and policy to be answered are the following: (1) What is the level of residential graywater use in a California city? (2) What demographic variables are associated with residential graywater use? (3) What is the perception of residential graywater use under Appendix G (Title 24, Part 5) and how does it compare with what graywater experts think? The following section details the methods used to answer these research questions.

METHODS

The current survey study was modeled after a similar study on residential graywater use conducted by the Water Conservation Alliance of Southern Arizona (CASA) from 1998 to 2000 (Little et al., 2000). Arizona changed its graywater guidelines to Title 18 (Chapter 9, Article 7) after results from the Water CASA study in Tucson were published (Little et al., 2008). The success of the study and its ability to impact legislation were the primary motivating factors in selecting Water CASA's study as a model. Of the many tools used in the Water CASA study, their survey model was chosen.

Surveys, the main research tool to gather data in sociological studies, were used in the current study because they helped to collect pertinent information regarding people's feelings, motivations, plans, and beliefs about a particular issue, e.g., residential graywater use. They also assisted in collecting socio-demographic information about the person's personal, educational, and financial background (Fink and Kosecoff, 1985) and how they might be linked with residential graywater use. An advantage of using surveys was that they offered the possibility of anonymity (Babbie, 1995), which in the case of measuring graywater use, especially illicit ones, was quite useful. Moreover, surveys were used to obtain a representative sample from the target population.

Since surveying an entire city was financially unfeasible for this study, a sample from a city was taken. The information gathered provided a clearer understanding of motivations for graywater use, related socio-demographic factors, its perceptions, and its influences. Surveys were used in this study to determine residential graywater use and understand it by providing a descriptive background on various socio-demographic factors, which in turn provided a suitable framework for running various statistical analyses. The information provided in the surveys also provided an explanatory base (Babbie, 1995) to answer the research questions previously posed. It was not necessary to sample for graywater and perform chemical and microbiological tests since there is sufficient secondary data available.

To answer the "how" and "why" questions regarding residential graywater use, a semi-structured interview was used (see Appendix C). These interviews helped to provide an open framework for two-way communication where thoughts about graywater use and policies could be openly discussed while still adhering to a base set of questions (Case, 1990).

Study Site

The City of Berkeley in California was chosen as the study site and single-family homeowners as the target population. Berkeley is located in Alameda County (see Figure 3) and is serviced by East Bay Municipal Utility District (EBMUD). The sample was taken from 556,474 households in Alameda County with a total population of 1,457,426 (2006 US Census estimate). The racial composition of residents in Alameda County is comprised of Caucasians (56.9%), Asians (24.2%), African Americans (13.8%), and Others (5.1%) (US Census, 2000). Surveys were sent to the sample, which comprised of randomly selected single-family homeowners within the City of Berkeley in Alameda County.

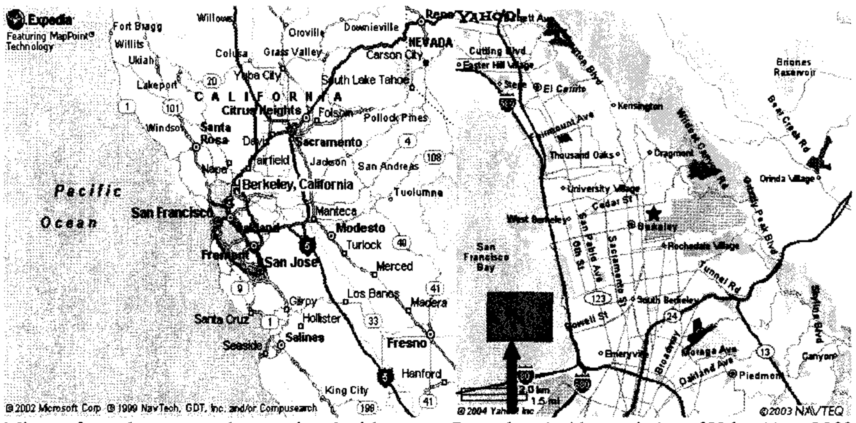

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Figure 3. Study site in Berkeley, CA.

The City of Berkeley has a population of approximately 102,049 (US Census estimate from 2003). For Berkeley, the ethnic composition is Caucasian (59.2%), followed by Asian (16.4%), then African American (13.6%), and Others (10.8%) (US Census 2000). Berkeley, California was picked as the study site for a few reasons. It is serviced by the East Bay Municipal Utility District (EBMUD), a bifunctional public municipality providing treated and wastewater service. EBMUD also has a graywater rebate program under its landscaping program. In terms of logistics, it was easier to send the surveys to residences in Berkeley from San Jose, California, the mailing origin of the surveys, because any follow-up work that was required and questions that arose were overall feasible to manage and address. In addition, staff from a non-governmental organization (NGO), Water Reuse Warriors (pseudonym), recommended Berkeley as a study site because it is a city well known for being environmentally conscious. This NGO will be discussed in later sections of this thesis.

Study Design and Data Collection

Before data collection started, information on graywater use was gathered at a water resource conference sponsored by the Water Resource Research Center in Phoenix, Arizona from June 20 to June 21, 2006. The topic of this conference was on how to provide water, using a limited and dwindling supply, to support Arizona's growing population. At this conference, details regarding the Water CASA study from 1998 to 2000 were obtained from Val Little, the lead researcher from the Water Conservation Alliance of Southern Arizona (CASA). She was contacted to further develop the Berkeley survey questionnaire based on the survey that was sent out from the Water CASA study. Other pertinent information was acquired to further refine the study design and data collection.

A CD ROM from Haines Criss-Cross was purchased to obtain a residential address directory for Alameda County and used to filter out 800 single-family homeowner addresses in Berkeley. 600 single family homeowner addresses were selected from the low to mid income wealth code (1.0 to 6.0) and 200 single family homeowner addresses from the high income wealth code (7.0 to 9.0), according to the wealth code rating from the Haines Criss-Cross CDROM and based on US Census statistics.

Single family homeowners were selected as the target population to study graywater use levels because of the following: (1) Any modifications made to the plumbing system for reusing graywater is overall more flexible and feasible in an owned home than in a rented one or an apartment and (2) Graywater use has been reported to occur mostly in residential areas (Christoba-Boal et al., 1995; Little et al., 2000). The survey did not identify the respondent due to the sensitive nature of the survey questions. The nondisclosure of survey respondents' identities was pursued per IRB protocol with accompanying documentation (see Appendix G). There were no major risks to the survey respondents while this study was conducted.

To create the list of addresses for mailing the surveys, a random address on Addison Street, which was far enough from the Pacific Ocean, was chosen so that a radius search could be performed. A distance of 0.4 miles was selected as a radius search because it provided a wider and more representative lot of residences with resulting wealth codes ranging from 3.1 to 7.0. The addresses were then printed onto Avery 5160 labels and put on No. 10 envelopes provided by the Environmental Studies department at San Jose State University.

A target survey return rate was set at 10% or 80 surveys from the original 800 sent. A 10% response rate was chosen because it fell within the range (10-40%) for a typical return rate on studies involving mailed surveys, especially ones with no monetary incentives (Ferguson, 2000; Kanuk and Bereson, 1975).

Printed surveys were mailed to the homeowners during the week of February 15th, 2008. The homeowners were given a month to fill out the survey and return them to the

Environmental Studies Department (Attn: Katherine Cushing) at San Jose State University in pre-paid postage envelopes (No. 6 3/4), initially included in the original No. 10 envelopes. The surveys were addressed to the "Current Homeowner" instead of the name of the addressee, along with a fictitious address of origin. The reason for not using the name of the addressee was to plan for sudden changes in home ownership. The fictitious address of origin was used to protect the survey respondents' identity and comply with regulations from the U.S. Postal Service. One adult homeowner was asked to fill out the survey.

In terms of the semi-structured interview, three public officials were interviewed about California's graywater regulations, graywater policy history, and perception (see Appendix F). The three officials included one person from the East Bay Municipal Utility District (EBMUD), one from the City of Berkeley, and one from the Department of Water Resources (DWR). Aside from public officials, a representative from the Water Reuse Warriors and a representative from EcoHouse in Berkeley, CA were also interviewed following the semi-structured interview questions from Appendix C. The names of the interviewees were kept confidential according to the conditions set forth in the IRB required and approved document (see Appendix G) for semi-structured interviews. Pseudonyms were used in the place of the real names of the interviewees so that they could openly discuss their views on graywater use, Appendix G (Title 24, Part 5), and related issues surrounding the two (see Appendix F) while maintaining anonymity.

In addition to the semi-structured interviews of public officials and affiliates of NGOs, thirty anonymous surveys were sent to attendees of graywater and water conservation workshops coordinated by the Water Reuse Warriors (pseudonym). It is a nonprofit organization located in Alameda County, CA that is promoting awareness about water conservation and graywater use. A representative from Water Reuse Warriors was instructed that the thirty surveys were to be filled out by people who did not receive the surveys in the main mailing.

Besides the two sets of surveys and semi-structured interviews, an analysis of the two sets of graywater regulations (Appendix G, Title 24, Part 5 and Title 18) were performed to help determine their effect on residential graywater use. Title 18 was chosen to compare with Appendix G (Title 24, Part 5) because it was one of the results of a successful two-year study conducted on residential graywater use by Water CASA in Arizona (Little et al., 2008).

Operationalization of Variables

Mailed surveys were the main tool used to answer research questions 1, 2 and 3 for the current study. The objectives of this study were to determine residential graywater use and how it is related to socio-demographic factors and perception of its use. To determine the association and interaction of socio-demographic variables with residential graywater use and how the perception of graywater use was influenced by Appendix G (Title 24, Part 5), various socio-demographic and perception variables were operationalized and entered into SPSS v. 16 for statistical analysis (see Table 4).

Table 4

Description of dependent and independent variables used in SPSS analyses.

Variables	Code Designation	Description
Dependent		
Graywater Use	*GW Use*	past and present use of residential graywater
Independent		
Age	*Age*	age of survey respondent
Gender	*Gender*	gender of survey respondent
Ethnicity	*Ethnicity*	ethnicity of survey respondent
Income	*Income*	annual household income of survey respondent
Education	*Edu_bachelor*	education of survey respondent, with emphasis on bachelor education only
Graywater Definition	*GW Definition*	Respondents agreeing with graywater definition
Knowledge of Graywater Regulations	*GW Know*	Respondents' knowledge of graywater regulations in CA; Appendix G (Title 24, Part 5)
Graywater Code Effectiveness	*GW Effect*	Respondents' view of the effectiveness of Appendix G (Title 24, Part 5) in promoting graywater use
Graywater as Renewable Resource	*GW Renew*	Respondents' view of graywater as potential renewable resource for water conservation
Graywater in Water Conservation	*GW Conservation*	Respondents' view of graywater's potential to conserve water
Interest in Replumbing for Graywater Use	*GW Interest*	Respondents' interest in replumbing their homes for reusing graywater

Data Analysis

Survey Results

The dependent variable was graywater use, with focus on both frequency and history of use in Berkeley, CA. The independent variables were socio-demographic factors like age, gender, ethnicity, education, and annual household income. Perception variables included how graywater is perceived and its knowledge, its potential in water conservation, and knowledge of the current graywater regulations in California. SPSS v.16 was used to run descriptive, bivariate analyses using CROSSTABS and binomial logistic regression analyses on the dependent and independent variables.

The main focus of this study was on the 800 randomly selected, single-family residences in Berkeley, with supporting observations from the smaller data set collected from the Water Reuse Warriors. Responses from the smaller survey set were also analyzed with SPSS v.16 using bivariate analysis (CROSSTABS) for descriptive, statistical analyses and binomial logistic regression for determining direction and magnitude of the relationship between the dependent and independent variables. Since the sample size was small ($N = 22$) from the Water Reuse Warriors and no statistical significance ($p < .05$) was determined from SPSS analyses, data from this sample were used to descriptively reinforce the observations made from the Berkeley sample.

Semi-structured Interviews

Responses to the questions from the semi-structured interviews were transcribed from the original audio recordings into a notebook; corresponding responses were collected and condensed for each question (see Appendix F). The responses from the semi-structured interviews were transcribed as they were given by each interviewee. Responses given by each interviewee for each of the questions (see Appendix F) were then chosen and refined based on relevancy to the study objectives before being used in the text of this thesis.

Document Review of Graywater Regulations

California's graywater use regulations under Appendix G (Title 24, Part 5) of the California Plumbing Code, was reviewed and used to help explain the various perceptions on residential graywater use in Berkeley, California. Appendix G (Title 24, Part 5) was also compared with Arizona's graywater use guidelines in Title 18 (Chapter 9, Article 7) to determine similarities and differences.

Limitations

Since the 800 surveys were written in English, they focused on a sample that was literate in English. This, however, excluded other residents who primarily read and write in languages other than English and who might also have used or are using graywater. The target population was single-family homeowners in Berkeley and this added a bias towards the study since it excluded those residents who were renting. There was also bias in choosing Berkeley since it is a city well known for being very environmentally conscious. The data from this survey would not be representative for all single-family homeowners in California and in cities across the country because not all of them have the same demographic data and environmental consciousness as Berkeley. The residential graywater use rates in both samples were also not weighted.

RESULTS

A total of 169 completed surveys were returned from the original 800 sent, giving a response rate of 21.1%. The data collected from the Berkeley and Water Reuse Warriors samples are presented in the following order: (1) the level of residential graywater use in the Berkeley sample, (2) socio-demographic variables associated with graywater use, and (3) the perception of residential graywater use under Appendix G (Title 24, Part 5) and how it compares with what graywater experts think. In the presentation of socio-demographic variables associated with graywater use, a brief description of the variable that was analyzed will precede a statistical analysis of its relationship with graywater use.

Level of Residential Graywater Use in Berkeley, CA Sample

Table 5

Past and present graywater use from the Berkeley sample, n = 49.

	Graywater Use	
	Frequency	Percent
No	118	70
Yes, currently	27	16
Yes, in the past, but not now	22	13
Total	167	99

Residential graywater use in the sample from Berkeley, CA was at 16%, with past use at 13% (see Table 5). All graywater use reported in the surveys was unpermitted. Graywater was used mainly for landscaping and gardening purposes. 47 out of 169

(28%) respondents indicated they were using or have used graywater for either purpose or both.

Table 6

Residential application sites for graywater from the Berkeley sample, $n = 47$.

Application Site	**Graywater Application per User (%)**
Bare Dirt	15
Lawn	45
Shade/Ornamental Trees	30
Fruit/Nut Trees	15
Wildflowers	23
Shrubs/Rose Bushes	64
Potted Plant	49
Herb/Vegetable garden	30
Compost	9
Other	9

Graywater was used mainly in the following areas: shrubs/rose bushes (64%), potted plants (49%), lawn (45%), shade/ornamental trees (30%), and herb vegetable gardens (30%), wildflowers (23%), and fruit/nut trees (15%) (see Table 6). About 15% of respondents said they were just pouring the graywater onto bare dirt. In the option for "Other" in applications of graywater, respondents (9%) were using their graywater for other purposes, like flushing toilets (see Table 6).

Table 7

Sources of graywater from the Berkeley sample, $n = 48$.

Graywater Source	**Percent of all sources (%)**
Washing machine	13
Bathroom sink	6
Bathroom shower/tub	37
Kitchen sink	44

The possible sources of graywater, as mentioned in the survey (see Appendix B), were from the following: the washing machine, bathroom sink, bathroom shower/tub, and kitchen sink. Of all reported sources used for graywater, 44% came from the kitchen sink (see Table 7).

Table 8

Graywater storage from the Berkeley sample, $n = 51$.

Graywater Storage		
Storage	Frequency	Percent
No	46	27
Yes	5	3
Total	51	30
Missing	118	70
Total	169	100

In terms of storing graywater, of the 49 respondents who reported that they were either currently using or have used graywater, 9% (5 out of 51) reported storing or have stored their graywater above ground (see Tables 8 and 9).

Table 9

Location of graywater storage from the Berkeley sample, $n = 5$.

Graywater Storage Level		
Location	Frequency	Percent
Above ground	5	3
Missing	164	97
Total	169	100

Graywater Use from the Water Reuse Warriors Sample

Graywater use from this small sample was at 81.8% for current usage (18 out of 22 respondents) (see Appendix E). The major source of graywater in this sample was from the washing machine (see Table 10) with major applications in fruit/nut trees (79%), herb/vegetable gardens (63%), rose bushes/shrubs (42%), wildflowers (32%), and shade/ornamental trees (26%) (see Table 11). In terms of storage, five respondents reported either currently storing or having stored graywater. The location of graywater storage from this sample varied, from above ground to underground and both (see Appendix E).

Table 10

Different sources of graywater from the Water Reuse Warriors sample, $n = 19$.

Graywater Source	**Percent of all sources (%)**
Washing machine	35
Bathroom sink	28
Bathroom shower/tub	25
Kitchen sink	13

Table 11

Various applications for graywater from the Water Reuse Warriors sample, n = 19.

Application Area	**Graywater Application per User (%)**
Bare Dirt	0
Lawn	5
Shade/Ornamental Trees	26
Fruit/Nut Trees	79
Wildflowers	32
Shrubs/Rose Bushes	42
Potted Plant	16
Herb/Vegetable garden	63
Compost	10
Other	21

Graywater Use, Application sites, and Sources between the Berkeley and Water Reuse Warriors Samples

Table 12

Comparison of application sites for graywater from the Berkeley (n = 47) and Water Reuse Warriors (N = 22) samples.

Application Site	**Graywater Application per User (%) (Berkeley, CA)**	**Graywater Application per User (%) (Water Reuse Warriors)**
Bare Dirt	15	0
Lawn	45	5
Shade/Ornamental Trees	30	26
Fruit/Nut Trees	15	79
Wildflowers	23	32
Shrubs/Rose Bushes	64	42
Potted Plant	49	16
Herb/Vegetable garden	30	63
Compost	9	10
Other	9	21
Graywater Use (Current), %	16	82

Table 13

Comparison of graywater sources from the Berkeley (n = 48) and Water Reuse Warriors (n = 19) samples.

Graywater Source	**Percent of all sources (%) (Berkeley, CA)**	**Percent of all sources (%) (Water Reuse Warriors)**
Washing machine	13	35
Bathroom sink	6	28
Bathroom shower/tub	37	25
Kitchen sink	44	13

Current graywater use was higher in the Water Reuse Warriors sample (82%) than the Berkeley sample (16%), though the sample size was small (N = 22). Even with a smaller sample size compared to the Berkeley sample, there were some striking similarities and differences between the two samples regarding application sites and sources of graywater.

Respondents from both samples used graywater in their herb and vegetable gardens with higher usage in the Water Reuse Warriors sample (63%). Respondents from both samples used graywater on most of the application sites, with the exception of the lawn, which was relied on more heavily by residents in the Berkeley sample (45%) (see Table 12). In terms of graywater sources, respondents from both samples relied on all given sources, but usage was relatively more even in the Water Reuse Warriors sample than the Berkeley sample (see Table 13). The kitchen sink was relied on more heavily in the Berkeley sample (44%) while the washing machine was the most relied upon Water Reuse Warrior sample (35%) (see Table 13).

Explanatory/Independent Variables and Graywater Use

To determine the relationship of the various socio-demographic variables to graywater use, a screening model was developed. If the predictor variable had a *p*-value less than .05 after using CROSSTABS, it was then passed to the next phase of the screening process. This next phase involved a logistic regression analysis using the dichotomized form (i.e., 0= Never Used, 1= Current and Past Use) of graywater use as the dependent variable.

Table 14

Nested data showing predictors of graywater use from the Berkeley sample following binomial logistic regression analysis.

	Graywater Use			Graywater Use			Graywater Use		
Predictor	**B**	**Sig.**	**Exp(B)**	**B**	**Sig.**	**Exp(B)**	**B**	**Sig.**	**Exp(B)**
Age	0.19	0.28	1.20	0.26	0.15	1.30	0.25	0.16	1.29
Gender	0.82 +	0.06	2.26	0.76+	0.08	2.13	0.78+	0.08	2.19
Ethnicity	0.61	0.25	0.54	-0.59	0.26	0.55	-0.58	0.27	0.56
Income	-0.22	0.01	0.80	-0.22*	0.02	0.80	-0.22*	0.02	0.80
Education	0.10 *	0.02	2.71	1.03*	0.02	2.79	1.02*	0.02	2.78
GW Definition	1.95 +	0.09	7.03	1.89+	0.10	6.65	1.93+	0.09	6.90
GW Renew	1.95 *	0.02	7.02	1.75*	0.04	5.75	1.77*	0.04	5.89
GW Conservation				0.52	0.10	1.68	0.54	0.10	1.71
GW Interest							-0.06	0.81	0.94
n = 155									

($p < .10$ (+); $p < .05$ (*)). Income= Annual Household Income; Education= collapsed education variable with emphasis on bachelor degree; GW Definition= definition of graywater; GW Renew= knowledge of graywater as potential renewable resource in water conservation pre survey; GW Conservation= potential of graywater in water conservation; GW Interest= interest of replumbing home for graywater use.

Binomial logistic regression was chosen to determine the direction and magnitude of the relationship between the predictor variables and the dichotomized form of the dependent variable. The predictor variables that had no significant effect ($p > .05$) after this test were taken out of the model using the backward elimination method (Norusis, 2008), with the remaining variables displayed in a nested data format (see Table 14).

The independent variables or predictors, as seen in Table 14, are all unmodified except for Education. This predictor was created from the original education variable by condensing the education groups into two groups, respondents with no bachelor's degrees and higher than a bachelor's degree and respondents with only a bachelor's degree. The education variable was modified because there was a trend showing bachelor degreed respondents using more graywater use than the other education groups. The dependent variable, graywater use, was dichotomized because there was an imbalance of respondents in the current and past use categories versus the never used category.

From Table 14, the parameter estimate, B, is an estimate of change in the dependent variable with a unit change in the independent variable (Garson, 2008). It affects the magnitude of the measure of deviation due to its relationship with the odds ratio, Exp(B). Exp(B) is the factor by which the odds of the dependent variable, graywater use, will change given a one unit increase in the independent variable (Garson, 2008).

Direct, constant effects on a dependent variable cannot be attained from logistic regression. Coefficients are statements of direct, constant change in the log of the odds of the dependent variable. Therefore, one must transform the coefficients to understand the independent variables' effects on the dependent variable. The exponentiated beta, Exp(B), is a statement of the proportional change in the odds ratio with each unit increase in an independent variable. One can use this information to determine a more user-friendly interpretation of the effects of each independent variable, the percentage change in the odds that results from each unit increase in each independent variable.

Table 14 shows that income and education affected the likelihood of using gray water ($p < .05$). For each unit ($10,000) increase in income, there was a decrease of approximately 20% in the odds of using gray water (Exp(B) = .80). Residents with only a bachelor's degree have odds of using gray water that are 178% greater than those with other educational levels (Exp(B) = 2.78).

The percentage change in the odds of using graywater for each demographic variable with significance is calculated by first subtracting 1 from the exponentiated beta value, Exp(B), then multiplying by 100. For example, the decrease of 20 percent in the odds of using graywater for each unit ($10,000) increase in income is calculated by subtracting 1 from .80. The resulting value is negative .20. This value is then multiplied by 100 to get the value of negative 20%.

Table 15

Statistical significance ($.1 > p > .01$) and deviation range of five predictor variables from the Berkeley sample.

Predictor	B	Sig.	Exp(B)	95% CI for Exp (B) Lower	Upper	(-) Deviation	(+) Deviation
Gender	0.78	0.08	2.19	0.91	5.30	1.29	3.11
Income	-0.22	0.02	0.80	0.67	0.96	0.13	0.16
Education	1.02	0.02	2.78	1.19	6.45	1.58	3.68
GWdef	1.93	0.09	6.90	0.72	65.82	6.17	58.92
GWrenew	1.77	0.04	5.89	1.08	32.22	4.82	26.33

Of the nine predictors of graywater use from Table 14, the following had statistical significance (.1 > p > .01): Gender, Income, Education (bachelor's degree or not), Graywater Definition, and Graywater as Renewable Resource. Of these five independent variables, demographic predictors, like Gender, Income, and Education, had the least amount of variation with a confidence interval of 95% when compared to the perception predictors (see Table 15). The significance of this observation will be discussed later in the section that involves a standard error analysis of statistical data generated.

Demographics of Berkeley and Water Reuse Warriors Samples

The age range of respondents in the Berkeley sample was comprised mainly of residents in their mid 30s to mid 50s (over 70%). The predominant gender for the respondents was female (61%). Most survey respondents (73%) had annual household incomes from $60,000 to $90,000 and above. In terms of education, the sample was well educated with 93% having a bachelor's degree and higher. The racial diversity of the sample was the following: Caucasian (87%), Asian (9%), Hispanic (2%), African American (1%), and Other (1%) (see Appendix E).

Thirty surveys were sent to Bay Area and other Northern Californian residents who attended workshops given by the Water Reuse Warriors. Twenty-two surveys were returned with a response rate of 73%. The age range of respondents from this sample was mainly composed of people from their mid 20s to mid 50s (82%). The predominant gender was female (68%). In terms of annual household income, most of the respondents were earning less than $30,000 (59%). A majority of the respondents had a bachelor's degree or higher (82%). The racial composition of from this sample comprised of the following: Caucasian (68%), Asian (4%), Hispanic (9%), and Other (18%) (see Appendix E). There was not any statistical significance in the SPSS analyses, however, from the small number of surveys that were returned.

Demographic Variables Associated with Residential Graywater Use

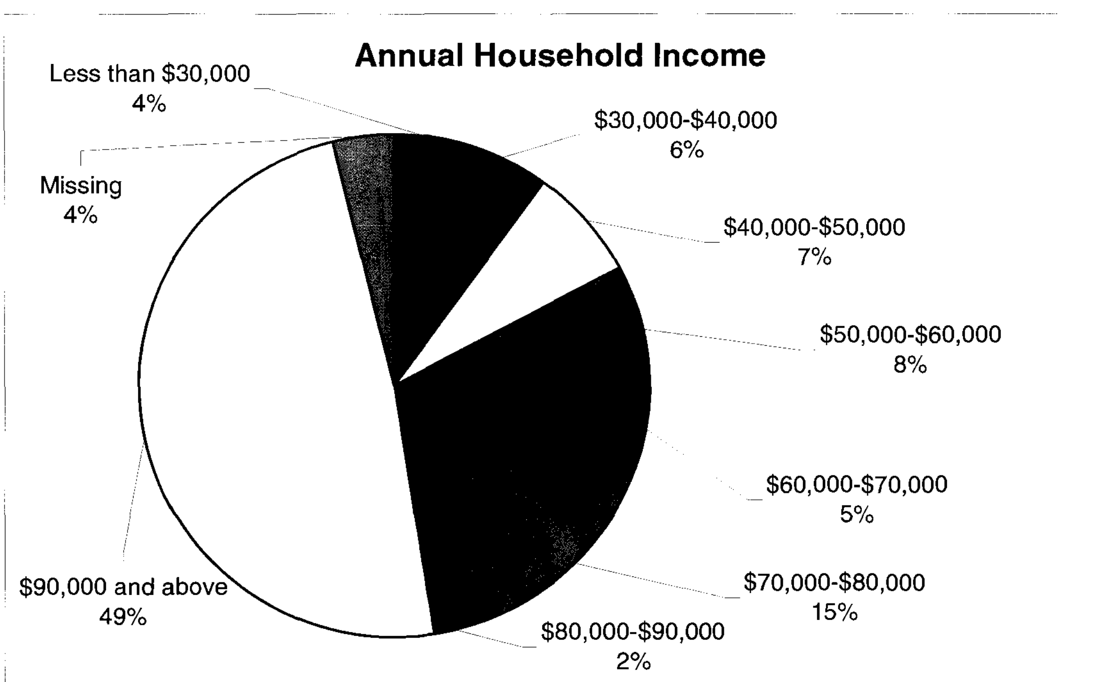

Figure 4. Annual household income from the Berkeley sample, n = 162.

Income

The demographic variables statistically evaluated in this study were age, gender, ethnicity, income, and education. Of these five variables, income, education and age were analyzed, with income and education showing significant statistical correlation with graywater use. In terms of annual household income, 600 residences were initially selected with income levels in the low to mid range (Wealth Code = 1.0 to 6.0) and 200 residences were selected with incomes in the high range with a wealth code of 7.0 to 9.0. A majority of survey participants (over 70%) were in the mid to high income level ($60,000 to $90,000 and above) (see Figure 4). There were also some survey respondents (n = 7) who did not indicate their income (see Table 16).

In the Water Reuse Warriors sample, most respondents (59%) had an annual household income of less than $30,000 (see Appendix E). This majority was followed by residents in the $40,000 to $50,000 income group (14%) and by residents in the $90,000 and above group (9%). Remaining residents represented approximately 4.5% for each of the other income groups (see Appendix E).

Table 16

Annual household income from the Berkeley sample, n = 162.

Income Level	Frequency	Percent
Less than $30,000	7	4
$30,000-$40,000	10	6
$40,000-$50,000	12	7
$50,000-$60,000	14	8
$60,000-$70,000	8	5
$70,000-$80,000	25	15
$80,000-$90,000	4	2
$90,000 and above	82	49
Sum	162	96
Missing	7	4
Total	169	100

Table 17

CROSSTABS analysis comparing annual household income and graywater use from the Berkeley sample, $n = 160$.

Crosstabulation of Income and Graywater Use

Annual Household Income		Never Used	Current and Past Use	Total
Less than $30,000 to $40,000	Count	5	12	17
	% within Income	29	71	100
$40,000 to $60,000	Count	18	8	26
	% within Income	69	31	100
$60,000 to $80,000	Count	25	8	33
	% within Income	76	24	100
$80,000 to $90,000 and above	Count	63	21	84
	% within Income	75	25	100
Total	Count	111	49	160
	% within Income	69	31	100

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	14.66	3	0.002
Likelihood Ratio	13.42	3	0.004
Linear-by-Linear Association	9.03	1	0.003
N of Valid Cases	160		

Income and graywater use. When a bivariate regression analysis was run for annual household income and graywater use (dichotomized), the resulting p-value was .002 indicating statistical significance and a relationship between the two (see Table 17). The income variable displayed consistency in statistical significance with graywater use by having a p-value of less than .05 ($p = .02$) (see Table 14), an indication of correlational significance. Residents in the survey with lower annual household incomes were using graywater more than residents with higher annual household incomes. Basically, for each unit ($10,000) increase in income, there was a decrease of approximately 20% in the odds of using gray water (Exp(B) = .80) (see Table 14).

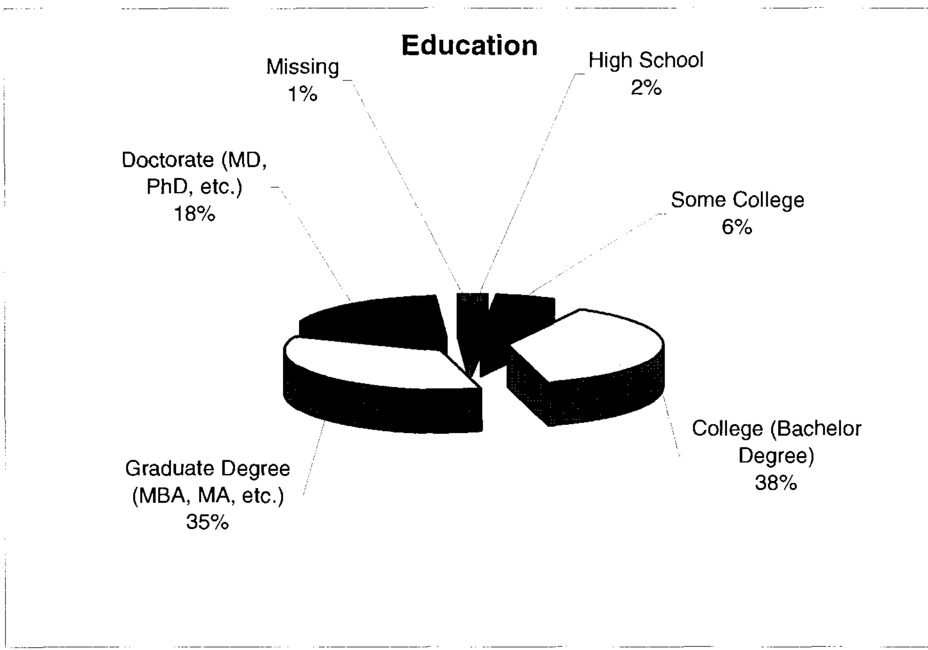

Figure 5. Education level of survey respondents from the Berkeley sample, *n* = 168.

Education

The second demographic variable showing statistical significance was education, with a focus on survey residents with only bachelor's degrees. A majority of survey respondents had at least a bachelor's degree (approx. 90% or 155 out of 169), with 38% having just a bachelor's degree (see Figure 5). Respondents with master's degrees made up 35% of the survey pool with 18% having doctorate degrees.

In the Water Reuse Warriors sample, 59% of the respondents had a bachelor's degree (see Appendix E). Approximately 23% of residents had a graduate degree.

Respondents with only a high school diploma and some college education represented 18% of the sample. There were no respondents with a doctorate degree.

Education and graywater use. From the cross-tabs analysis in Appendix E, it appears that the percentage of survey respondents with only a bachelor's degree and who have used or are currently using graywater (approx. 40%) is larger than the other education groups, even though the results were not statistically significant ($p = .29$). As a result, the education variable was collapsed to form two groups: respondents with only bachelor's degrees and respondents who do not have bachelor's degrees and who have advanced degrees.

From this observation, a bivariate analysis using CROSSTABS was run to determine any correlation between the modified education variable with two collapsed education groups and graywater use. A significant relationship ($p = .03$) was determined in the bivariate analysis between those two variables (see Table 18). The *p*-value for the collapsed education variable in the binomial regression analysis was .02 (see Table 14), indicating correlational significance with graywater use. According to Table 14, residents with only a bachelor's degree have odds of using gray water that are 178% greater than those with other educational levels (Exp(B) = 2.78). In other words, residents with only a bachelor's degree from the Berkeley sample were more likely to use graywater than residents with either no bachelor's degrees or residents with advanced degrees.

Table 18

CROSSTABS analysis of education, with emphasis on bachelor degrees, and graywater use from the Berkeley sample, n = 166.

Crosstabulation of Education and Graywater Use

Education	Count and Percentage	Never Used	Current and Past Use	Total
Not Bachelor degree	Count	78	24	102
	% within Education	76	24	100
Bachelor degree	Count	39	25	64
	% within Education	61	39	100
Total	Count	117	49	166
	% within Education	70	30	100

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	4.561	1	0.03		
Continuity Correction	3.845	1	0.05		
Likelihood Ratio	4.496	1	0.03		
Fisher's Exact Test				0.04	0.03
Linear-by-Linear Association	4.533	1	0.03		
N of Valid Cases	166				

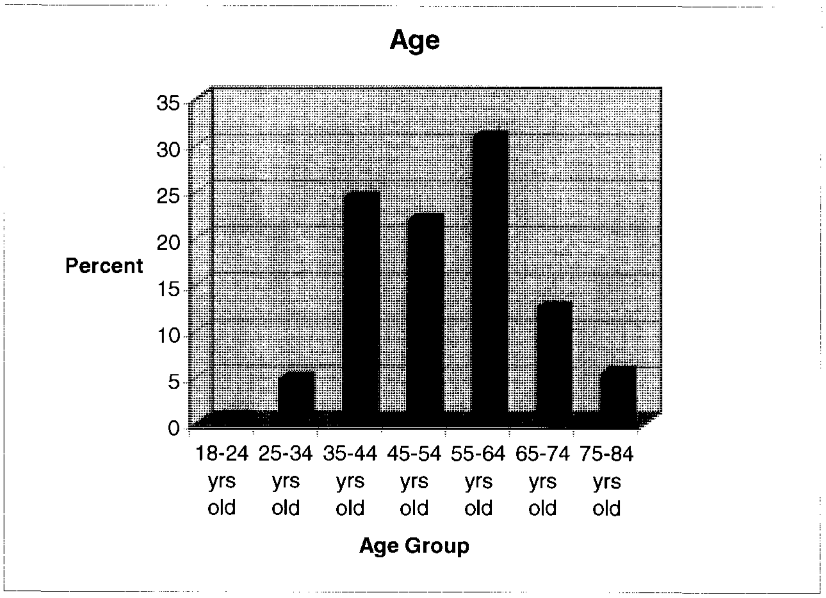

Figure 6. Age distribution from the Berkeley sample, $N = 169$.

Age

Out of the 169 surveys that were returned, the mean age of respondents was found in the 45 to 54 age group range, with a majority of respondents from the 55 to 64 year old age bracket. This bracket was followed by respondents in the 35 to 44 year old range, followed by respondents in the 45 to 54 year old bracket. The age distribution was relatively normal with a majority of respondents in the middle age to senior age categories (see Figure 6).

In the Water Reuse Warriors sample, half of the respondents were in their mid 20s to mid 30s (see Appendix E). This age group was followed by respondents in their mid 30s to mid 40s (18%). Respondents in the 18 to 24 year old and 45 to 54 year old groups each represented approximately 14%. The 55 to 64 year old group had the smallest representation with only 4% (see Appendix E).

Table 19

CROSSTABS analysis on age and graywater use from the Berkeley sample, $n = 167$.

Crosstabulation of Age and Graywater Use

Age		Never Used	Current and Past Use	Total
Young Adult to Middle Age	Count	43	7	50
	% within Age	86	14	100
Middle Age to Senior	Count	72	37	109
	% within Age	66	34	100
Senior	Count	3	5	8
	% within Age	38	63	100
Total	Count	118	49	167
	% within Age	71	29	100

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	11.03	2	0.004
Likelihood Ratio	11.38	2	0.003
Linear-by-Linear Association	10.77	1	0.001
N of Valid Cases	167		

Age and graywater use. The demographic variable, age, did not show any statistical significance in relation with graywater use ($p = .16$) in the nested data table (see Table 14). There was, however, statistical significance when age was analyzed with graywater use in a bivariate analysis using CROSSTABS, with the resulting p-value being .004 (see Table 19).

Socio-Demographics and Graywater Use between the Berkeley and Water Reuse Warriors Samples

Table 20

Comparison of education, income, and age with graywater use between Berkeley and Water Reuse Warriors samples.

Predictors		**Berkeley, CA**			**Water Reuse Warriors**		
Demographics	***Range***	***N***	**Mean**	**Std. Deviation**	***N***	**Mean**	**Std. Deviation**
Annual Household Income	1 to 4	162	3.16	1.05	22	1.73	1.12
Education	0 to 1	168	0.39	0.49	22	0.59	0.50
Age	1 to 3	169	1.76	0.54	22	1.18	0.39
Graywater Use	0 to 1	167	0.29	0.46	22	0.86	0.35

In terms of socio-demographic variables, respondents from the Water Reuse Warriors sample had a lower annual household income (mean = 1.73), were less educated (mean = .59), and younger (mean = 1.18) than respondents from the Berkeley sample. Graywater use, past and present, was higher among respondents in the Water Reuse Warriors sample (mean = .86) than in the Berkeley sample (mean = .29) (see Table 20). Residents with low annual household incomes from the Water Reuse Warriors sample were using graywater more than residents with higher annual household incomes. Besides household income, residents from the Water Reuse Warriors sample with a college education and above were using graywater more than those with less education. The code designations and explanations for each of the demographic variables are found in Appendix D.

With the exception of non-empirical data collected from the interviews, the data collected from surveys sent to the Berkley sample exhibited some statistical variation, especially the perception variables used in the SPSS analyses (see Table 15). The following section explains the variation seen in the various predictor variables that were used in the SPSS analyses.

Standard Error Analysis

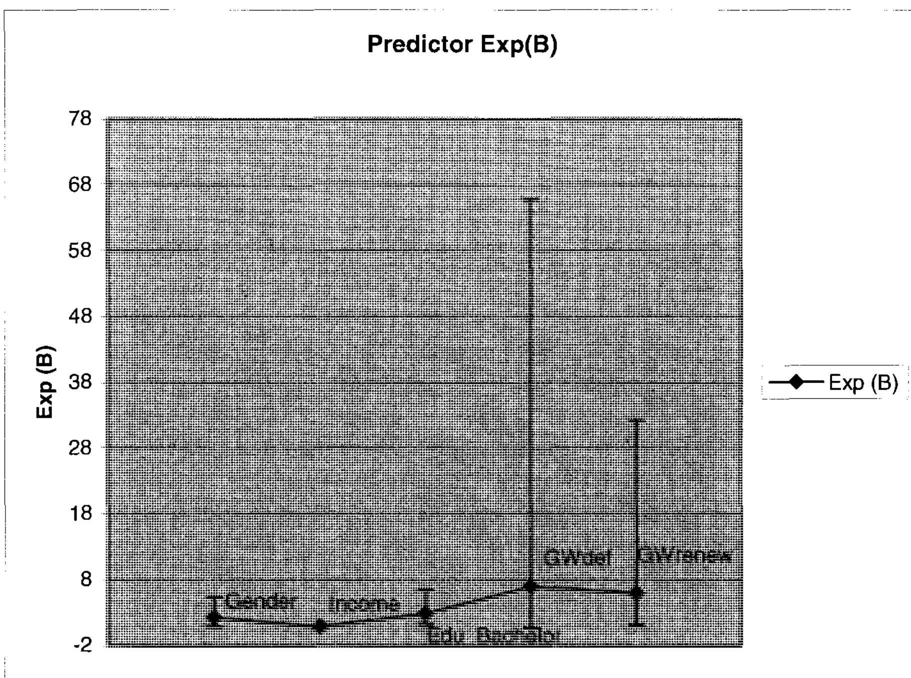

Figure 7. Range of deviation for predictors of graywater use in Berkeley sample.

The five predictors of graywater use, determined from running statistical analyses in this study, were gender, income, education, definition of graywater, and graywater as a renewable resource for water conservation. The deviation is smaller for the demographic variables and much larger for the perception variables (see Table 15 and Figure 7) because B, or parameter estimate, is greater than 1 and close to 2 for the perception variables. The parameter estimate, B, is an estimate of change in the dependent variable with a unit change in the independent variable (Garson, 2008). It affects the magnitude of the measure of deviation due to its relationship with the odds ratio, Exp(B). Exp(B) is the factor by which the odds of the dependent variable, graywater use, will change given a one unit increase in the independent variable (Garson, 2008). The direction of change for Exp(B) is determined by the mathematical sign of the parameter estimate, B.

Exp(B) is computed by taking the natural logarithm '*e*' raised to the value of the parameter estimate, B. The following equations illustrate the relationship between the parameter estimate B and the odds ratio Exp(B).

Equation 1:

Logistic Regression:

$\text{Log}[\ P(\text{event})/\ P(\text{no event})\ ] = B_0 + B_1X_1 + B_2X_2 + \ldots B_pX_p$ (Norusis, 2008)

Equation 2:

Odds ratio (of event happening):

Odds ratio = Exp(B) = 2.718^(B) (Garson, 2008)

Equation 1 describes the logistic regression model, with the left hand side of the equality predicting the natural log of the odds that an event will occur, or logit. B_0 is the intercept; B_1 to B_p are the regression coefficients, and X_1 to X_p are the independent variables (Norusis, 2008). Values of the parameter estimate, B, range from negative to positive infinity, with the value of 0 showing no effect on the dependent variable by the independent or predictor variable (Garson, 2008). Any parameter estimate (B) that is greater than 1 will have its resulting odds ratio value raised exponentially. This is shown in the great variation in the odds ratio values for the perception variables (see Table 15 and Figure 7).

Perception of Residential Graywater Use and Appendix G (Title 24, Part 5)

Graywater use was observed to be at a combined rate (past and present use) of 29% in the Berkeley sample and 86% in the Water Reuse Warriors sample. Graywater was also used to irrigate a variety of landscape and garden plants, with its sources from four different places within the home. Demographically, graywater use was shown to be statistically correlated with lower income households and people with only bachelor's degrees. This next section describes the perception of graywater use under Appendix G (Title 24, Part 5).

Table 21

Agreement with definition of graywater from the Berkeley sample, $N = 169$.

Definition of Graywater

	Frequency	Percent
No	27	16
Yes	142	84
Total	169	100

Respondents from the Berkeley sample indicated that graywater has an impact in addressing water conservation issues. Survey respondents were asked about whether they agreed with the definition of graywater: water that is untreated from your bathroom sink, shower area, kitchen sink (vegetable wash water), and washing machine. Over 80% of all survey respondents (see Table 21) indicated that they agreed with the given definition of graywater.

Table 22

Graywater as renewable resource in water conservation from the Berkeley sample, n = 168.

Graywater as Renewable Resource

Opinion	Frequency	Percent
No	33	19.5
Yes	135	79.9
Total	168	99.4
Missing	1	0.6
Total	169	100

When asked about graywater as a potentially renewable resource in conserving water, a majority of survey respondents (80%) said that it is a potentially renewable resource in addressing water conservation issues (see Table 22). On graywater's potential in addressing challenges in water conservation, over 80% of all survey respondents believed that graywater has some potential to a great deal of potential (see Table 23).

Table 23

Graywater's potential in conserving water from the Berkeley sample, n = 168.

Graywater in Water Conservation

Opinion	Frequency	Percent
Don't Know	17	10.1
A Little/Some	40	23.7
A Great Deal/A lot	111	65.7
Total	168	99.4
Missing	1	0.6
Total	169	100

In terms of the survey respondents' knowledge of Appendix G (Title 24, Part 5), roughly 75% of the sample had no knowledge of the regulation (see Table 24). Approximately 25% of all respondents indicated that they know very little to some information about Appendix G (Title 24, Part 5) (see Table 24).

Table 24

Knowledge of Appendix G (Title 24, Part 5) from the Berkeley sample, n = 168.

Knowledge of Appendix G (Title 24, Part 5)

Level of Knowledge	Frequency	Percent
Nothing	126	74.6
Very Little	29	17.1
Some Information	13	7.7
Total	168	99.4
Missing	1	0.6
Total	169	100

Of those who had very little to some information about Appendix G (Title 24, Part 5), 22 respondents out of 41 (54%) said that they relied on self-study, reading journals, newspapers, and going in the internet, as opposed to relying on a friend or the government (see Appendix E). Respondents who marked "Other" as a choice for where they received information regarding graywater and Appendix G (Title 24, Part 5) mentioned the following sources: KQED, Berkeley Ecohouse, KPFA, academia, wastewater experience, green building experience, and interest from neighbors.

On the effectiveness of Appendix G (Title 24, Part 5) in promoting graywater use in California, approximately 74% of survey respondents (31 out of 42) believed that Appendix G (Title 24, Part 5) is not effective in promoting graywater use (see Table 25).

Table 25

Effectiveness of Appendix G (Title 24, Part 5) in promoting graywater use from the Berkeley sample, $n = 42$.

Graywater Code Effectiveness

Opinion	Frequency	Percent
Don't Know	9	5.3
Not Effective	31	18.3
Somewhat Effective	2	1.2
Total	42	24.9
Missing	127	75.1
Total	169	100

Reasons given for the ineffectiveness of Appendix G (Title 24, Part 5) were mainly associated with fees and inspections from the permitting process (see Appendix E). Other reasons were from bureaucracy, negative public relations on health issues associated with graywater use, the lack of a financial incentive and encouragement for graywater use, and an overall restrictiveness of Appendix G (Title 24, Part 5).

Perception of Graywater and Appendix G (Title 24, Part 5) from the Water Reuse Warriors Sample

The perception of graywater in this very small sample was positive. The respondents from the NGO sample, on average, agreed with the definition of graywater from the survey and had a very positive perception of graywater being a renewable resource and its potential in conserving water (see Figure 8).

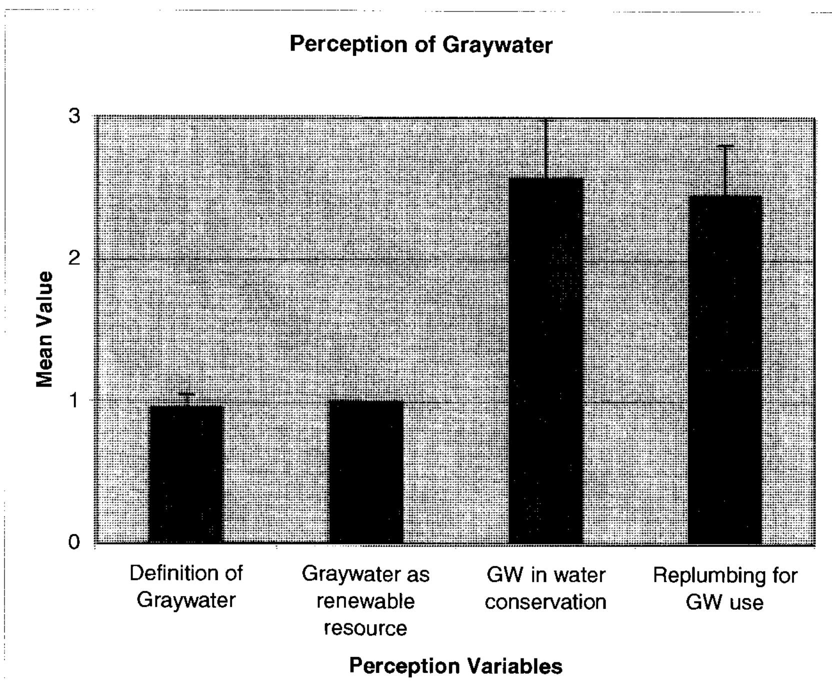

Figure 8. Perception of graywater from the Water Reuse Warriors sample.

In terms of the perception of Appendix G (Title 24, Part 5), survey respondents from this group knew relatively more about the regulation, but they perceived Appendix G (Title 24, Part 5) as ineffective in promoting graywater use (see Figure 9). Reasons given for Appendix G (Title 24, Part 5) being ineffective were mainly from fees and inspections (see Appendix E). Other reasons were from overly restrictive specifications, lack of incentives, rebates and education for the public, and bureaucracy, with specific reference to the permit approval process.

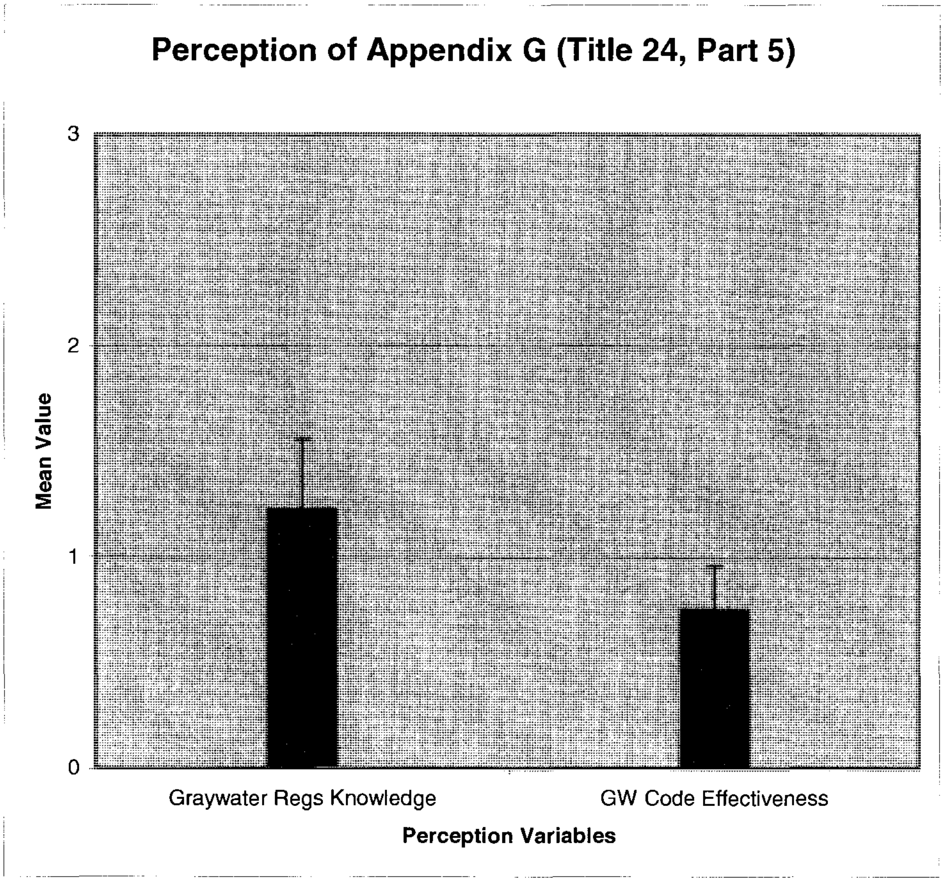

Figure 9. Perception of Appendix G (Title 24, Part 5) from the Water Reuse Warriors sample.

Perception of Graywater and Appendix G (Title 24, Part 5) between the Berkeley and Water Reuse Warriors Samples

The perception of graywater was positive between the two samples. However, the perception of Appendix G (Title 24, Part 5) from the Berkeley sample was not favorable and there were some notable differences when compared with the same perception variables from the Water Reuse Warriors sample (see Table 26).

Table 26

Comparison of graywater perception variables between the Berkeley and Water Reuse Warriors samples.

Predictors	**Berkeley, CA**				**Water Reuse Warriors**		
Graywater Perception and Appendix G (Title 24, Part 5)	***Range***	***N***	**Mean**	**Std. Deviation**	***N***	**Mean**	**Std. Deviation**
Definition of Graywater	0 to 1	169	0.84	0.367	22	0.96	0.21
Graywater Regs Knowledge	0 to 3	168	0.33	0.614	22	1.23	0.75
GW Code Effectiveness	0 to 3	42	0.83	0.49	20	0.75	0.44
Graywater as Renewable Resource	0 to 1	168	0.80	0.398	22	1	0
GW in Water Conservation	0 to 3	168	2.46	0.928	21	2.57	0.93
Replumbing for GW Use	0 to 3	169	1.74	0.99	20	2.45	0.76

For example, respondents from the Water Reuse Warriors sample knew more about Appendix G (Title 24, Part 5) (mean = 1.23) than respondents from the Berkeley sample (mean = .33). In terms of graywater as a renewable resource and its potential in water conservation, respondents from the Water Reuse Warriors sample had a more favorable view than respondents in the Berkeley sample, visible in the differences between the mean values (see Table 26). Another notable difference is that there was a greater interest to replumb homes for using graywater in the Water Reuse Warriors sample than in the Berkeley sample. Code designations for each of the perception variables are found in Appendix D.

Interviews with Graywater Experts

In general, residents from both samples agreed with the definition of graywater from the survey. They also had a positive perception of graywater as a renewable water resource, in its potential to conserve water, and in its use around the home. However, their knowledge of Appendix G (Title 24, Part 5) was at a minimal level and their opinion of its effectiveness in regulating graywater use was unsatisfactory. The third research objective was to determine the perception of graywater and Appendix G (Title 24, Part 5) and how they compared with assessments from different water reuse experts.

Interviewees were asked the following questions related to graywater use: (1) the history of how Appendix G (Title 24, Part 5) was first formed, (2) challenges in forming those regulations with stakeholder input, (3) the role that public perception and NGOs play in graywater regulation, and (4) personal opinions regarding Appendix G (Title 24, Part 5) and the current and future role graywater plays in water conservation. The following is a summary of the interviews conducted from five state, local and non-profit agencies: California Department of Water Resources, East Bay Municipal Utility District, the City of Berkeley, EcoHouse, and Water Reuse Warriors (pseudonym).

Appendix G (Title 24, Part 5) was created in response to the drought in the 1970s in California. There were challenges in setting guidelines for the proper use of graywater, given the potential risks from its use. One particular challenge came from the perception of graywater. When Appendix G (Title 24, Part 5) was first written by the California Department of Water Resources, policy makers had the perception that graywater was comparable to sewage.

With this rather cautious mindset as a focus, several requirements and calculations for certain tests, like soil percolation rates, were developed and implemented. The specific tests are "daunting to the average person," according to a representative from the Ecohouse. Appendix G (Title 24, Part 5) posed a challenge for potential graywater users because there was no ease of use for the graywater produced. Appendix G (Title 24, Part 5) was thus not written with the public's interest in mind, according to a representative from the Water Reuse Warriors.

To have a set of guidelines that are more inclusive, there needs to be cooperation among all stakeholders, a consensus among the interviewees. In terms of graywater, the following stakeholders were mentioned by all five interviewees: water utilities, health departments or county health agencies, planning departments, green building advocates, NGOs, different lobbying groups, plumbers, and residential users. This cooperation is critical in reconciling the growing interest of the general public in using graywater and the current requirements regulating its use under Appendix G (Title 24, Part 5).

According to an official from the California Department of Water Resources (DWR), there would be more legislative support to amend Appendix G (Title 24, Part 5) if more people were using graywater. An EBMUD official stated that there is "a large group of people" showing interest in graywater by diverting it to their landscape. This interest has been further developed and promoted by the Water Reuse Warriors, which a representative from the EcoHouse praised as influencing the movement to change Appendix G (Title 24, Part 5). However, the EBMUD official stated that this interest is being hindered by the steps required to obtain a graywater use permit under Appendix G (Title 24, Part 5), which are quite “onerous.”

In terms of the effectiveness of Appendix G (Title 24, Part 5), four out of the five interviewees said that it should be changed. The EBMUD official stated that Appendix G (Title 24, Part 5) is not effective because “no one is following [it] legally.” In the last five years, according to the EBMUD official, the permit and planning office in Alameda and Contra Costa counties received only a handful of permitting applications for graywater. An official from DWR stated that Appendix G (Title 24, Part 5) needs to be changed because there are “too many obstacles” to get a graywater system approved.

There was general consensus, however, among the five interviewees that graywater plays a key role in water conservation for the present and will do so for the foreseeable future in California. Some interviewees mentioned different ways that graywater use can be beneficial for water conservation. For example, an official from DWR mentioned that graywater use should be combined with rainwater harvesting to address water shortage issues in California.

For the most part, the interviewees and respondents from both samples felt that graywater plays an important role in water conservation. In terms of the effectiveness of Appendix G (Title 24, Part 5), most interviewees (four out of five) agreed that the regulation is ineffective and should be changed, an opinion shared by a majority of respondents from both samples.

DISCUSSION

Level of Residential Graywater Use in Berkeley, CA Sample

The current level of residential graywater use in the Berkeley sample was at 16%, with 82% from the Water Reuse Warriors. These two use levels are higher than the 13% reported from the 1998-2000 residential graywater study by Water CASA (Little et al., 2000) and the 7% from the 1999 SDA study of U.S. households (Roesner et al., 2006). The relatively higher graywater use levels are biased because Berkeley is well known for being environmentally conscious. The smaller sample ($N = 22$) was influenced by the Water Reuse Warriors, an NGO promoting graywater use and water conservation.

The sources of graywater from the two samples came from the bathroom tub and sink, along with the shower and the kitchen sink, with the Berkeley sample showing a majority of the graywater sourced from the kitchen sink (44%) (see Table 13). Except for the kitchen sink, these sources are all allowed under Appendix G (Title 24, Part 5). Little et al. (2000) found that fecal coliform concentrations were generally higher in households using graywater from the kitchen sink. According to Christova-Boal et al. (1995, p. ES-3), the kitchen sink is a "possible source" of graywater, but it can be contaminated with grease, oils, and food particles; since wastewater from the kitchen sink also accounts for 5% of the "average" household use, its use is insignificant and not recommended. The kitchen sink is, therefore, not a good source of graywater mainly due to the risk of fecal contamination (Little et al., 2000) and related illnesses.

A majority of the survey respondents in the Berkeley and Water Reuse Warriors samples were using their graywater to irrigate their landscape and various plants and trees, which is very encouraging (see Table 6). The survey data collected from the Berkeley and Water Reuse Warriors samples indicate a high percentage of graywater use in herb and vegetable gardens, 30% and 63% respectively (see Table 12). However, the observed use of graywater to irrigate herb and vegetable gardens is in direct violation of graywater use conditions found in Appendix G (Title 24, Part 5). In this appendix, there is a specific prohibition of graywater use on herb and vegetable gardens, per Section G13 under Health and Safety. The graywater use guide for California by the DWR also shows a graphic prohibiting graywater application on herb and vegetable gardens (see Figure 10).

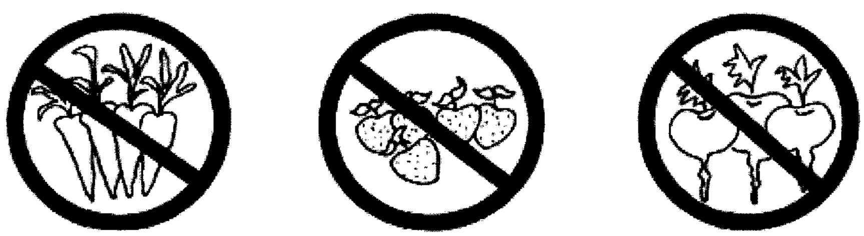

Figure 10. Prohibited uses of graywater from a graywater use guide (DWR, 1995).

Graywater application is prohibited on food crops because of the potential risks of disease transmission, primarily due to high concentrations of fecal coliform (Roesner et. al, 2006). This observation on the potential for disease transmission from graywater use was also corroborated by Jamrah et al. (n.d.), who noted that 88% of those opposed to using graywater, from its survey, did so because of health risks. From personal experience, the use of soapy graywater, especially bathroom sink water, on vegetable and herb gardens can leave an unsightly and powdery coating on the vegetable or herb after a period of drying. The prohibition of graywater use to irrigate herb and vegetable gardens might come from such an unaesthetic and possibly unhealthy appearance.

The fact that some survey respondents are using or have used graywater to irrigate their herb and vegetable gardens (see Table 12) indicates that California's graywater use guide might be insufficient and ineffective in conveying its potential risks. What the data from the current study are showing is a need for greater public outreach by local and state government on the proper and safe use of graywater in the home. This is also a recommendation made by Christova-Boa et al. (1995) from their two survey studies and Water CASA from their residential graywater study (Little et al., 2000).

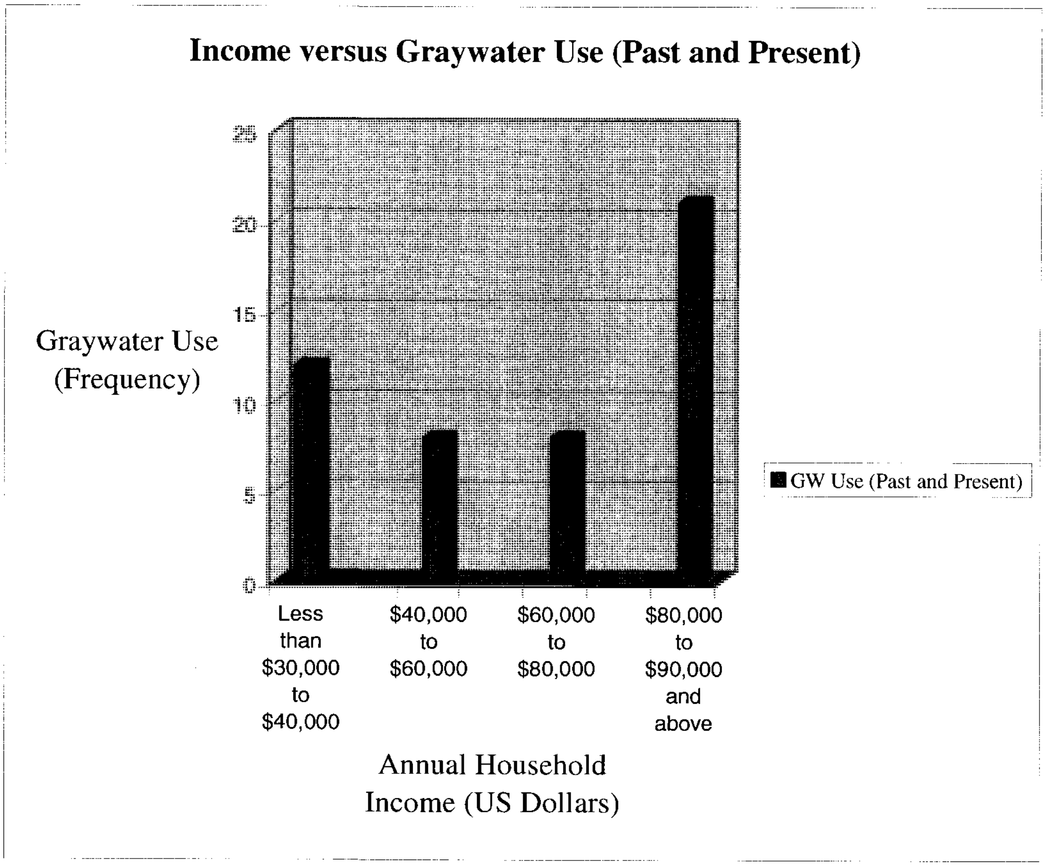

Figure 11. Annual household income versus graywater use (past and present) from the Berkeley sample, n = 160.

Income

Survey data show that while a great majority of Berkeley survey respondents have a high annual household income (see Figure 4), residents with lower annual household incomes (less than $30,000 to $80,000) were significantly more likely to use graywater (see Table 14) than those in the higher income bracket ($80,000 and above) (see Figure 11). This finding is corroborated by the Water CASA study from 1998 to 2000, which was conducted before the graywater regulations in Arizona were changed to what they are now in Title 18. Residents with lower annual household incomes were using graywater more than those in the higher income brackets.

The opposite was observed in the sociological arena. In a survey study that researched the influence of socio-demographic variables with environmental concern across various geographical regions, Guagnano and Markee (1995) observed that residents with lower income levels were more likely to place responsibility of protecting the environment on government and business rather than on themselves. Lower income residents were also more likely to report the complexity of actions needed to protect the environment. Both of these findings from Guagnano and Markee (1995) do not support the current finding of lower income households using more graywater than those with higher incomes. Using graywater around the home generally requires a person to take responsibility for protecting the environment and accept the complexity of its use.

Household income, however, was observed to be positively correlated to what Klineberg, McKeever, and Rothenbach (1998, p.748) termed as "pro-environmental behaviors." Klineberg et al. (1998) observed that people with higher incomes were more pro-active in protecting the environment by making informed choices in what they were buying and recycling materials. This finding is contrary to the current finding of lower income households using more graywater than those with higher incomes.

The observation from the Berkeley sample showing lower income residents using graywater more than those with higher incomes makes sense because the act of using graywater for non-potable activities saves money on the water bill. Similarly, residents with lower incomes from the Water CASA study were also using graywater more than those in the higher incomes because by diverting the graywater for other purposes they were saving money from having to empty their septic tanks often. The finding from the current survey study is contrary to what Guagnano and Markee (1995) found because of differences in geographical regions. There is a high bias in the current study because Berkeley is socially well known for being environmentally conscious and pro active.

Additional research studying the relationship between income and residential graywater use needs to be conducted given the sparse data on the topic and findings from related sociological studies. Further research on income and residential graywater use from an unbiased sample would give the current finding more significance and credibility.

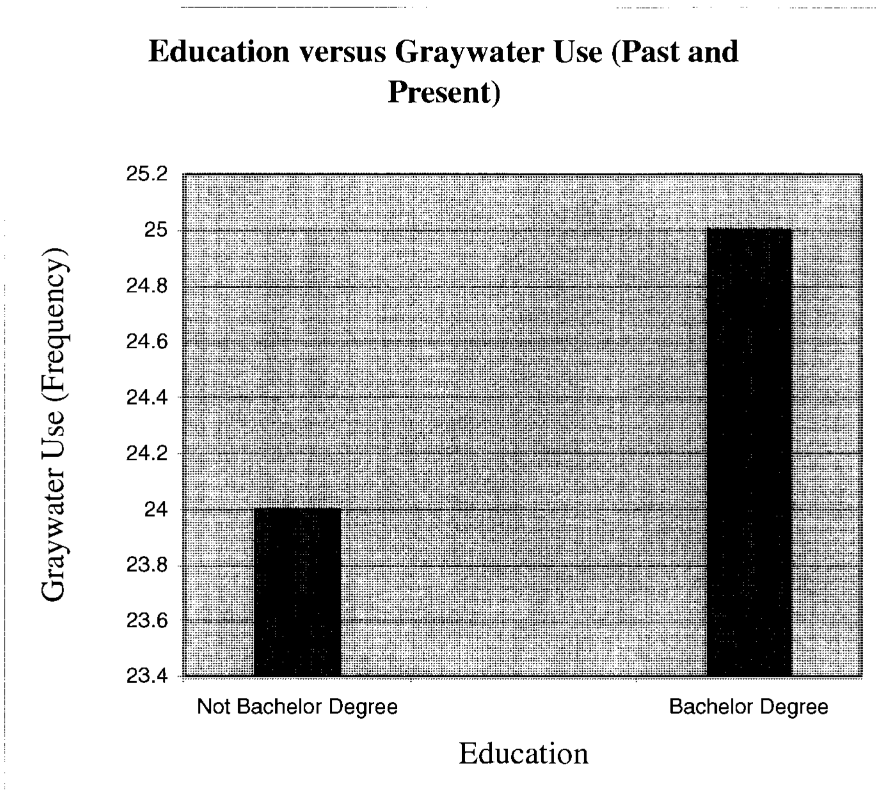

Figure 12. Education and graywater use from the Berkeley sample, n = 166.

Education

According to the US Census from 2000, residents in Berkeley are well educated (approximately 79%), from some college experience to higher academic pursuits, like graduate and doctorate degrees. Over 90% of all survey respondents from the Berkeley sample have a college degree or higher (see Figure 5). It was determined with statistical significance (see Table 14) that residents with only a bachelor's degree were using graywater more than those with other educational levels (see Figure 12).

The positive association between education, though not specific to a baccalaureate education, and environmental awareness was affirmed by a small study at the University of Wisconsin at LaCrosse. In that study, Schmidt (2007) determined that students who enrolled in an introductory class on environmental issues (ENV 201) had more "pro-environmental" attitudes than those who did not attend the course. Similarly, Guagnano and Markee (1995) observed that education is significantly and positively associated with environmental awareness from their survey study of socio-demographic factors associated with environmental concern.

Likewise, Klineberg et al. (1998) noted that people who are more educated tend to be more aware of their environment. They were thus more determined to act when there was a need in solving environmental issues.

Liu (2006) observed that people with a higher level of education were more likely to support recycled water use. However, this finding from Liu (2006) and others from Guagnano and Markee (1995) and Klineberg et al. (1998), which associate increased education to increased environmental awareness and concern, do not corroborate the current study's finding regarding people with only bachelor degrees and their tendency to use graywater more than those with other education levels. Being more educated and thus more environmentally conscious and aware is uncertain, especially in light of the current study's finding between education and graywater use.

An explanation for graywater use being higher among respondents with only bachelor's degrees than those in other education levels could be that people with only a bachelor's degree tend to realize the great need for resource conservation from participating in the work force early on in life. People with higher degrees, on the other hand, tend to be more occupied with their field of study and the pursuit of financial success. This current finding could also be attributed to the strong pro-environmental influences endemic to Berkeley seen only in residents with only a baccalaureate education.

Without a doubt, due to the lack of available data on education and graywater use and the contradictory findings from related sociological studies, more research needs to be conducted to further clarify the influence that education has on residential graywater use. Additional research is also necessary to explain why people with only bachelor's degrees were using graywater more than those with other educational levels, in order to further substantiate this significant finding.

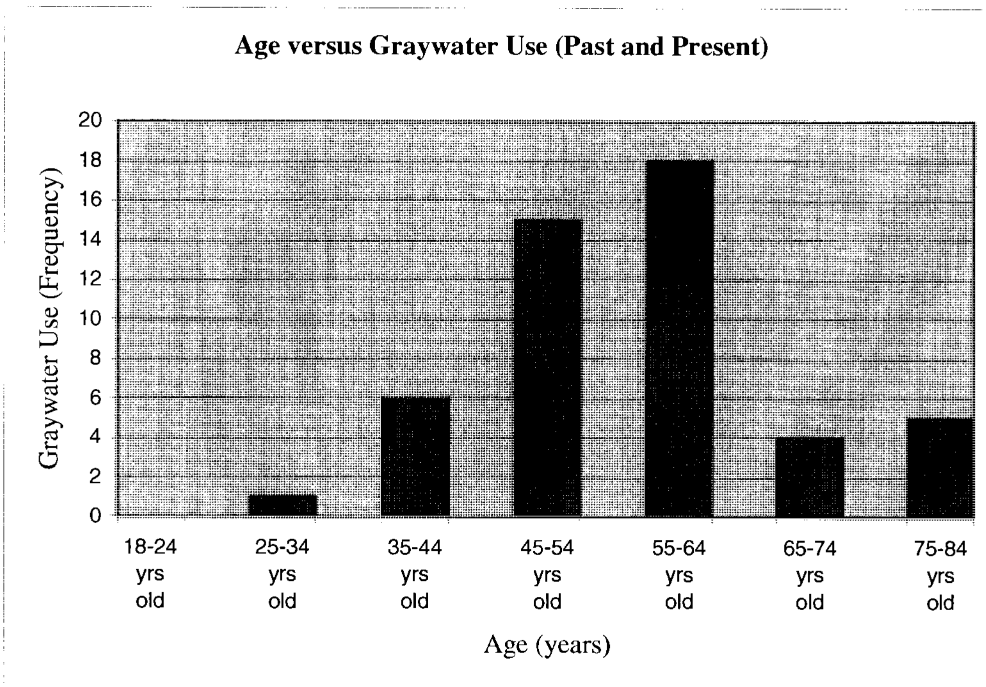

Figure 13. Correlation of age with residential graywater use from the Berkeley sample, $n = 167$.

Age

Graywater use was highest for respondents in the 55 to 64 year old group (see Figure 13). There was no statistical significance found between age and graywater use in the nested data table (see Table 14) and no literature correlating age and graywater use. There is, however, literature support for age and environmental concern, which graywater use advocates.

Guagnano and Markee (1995) observed that residents who were 65 years old and older placed more trust in industry, business and government to protect the environment than other age groups. The residents in this age group were thus less confident in their own abilities to protect the environment.

Liu (2006) determined that younger people were not more likely to support water reuse projects. This finding was reached when researching which demographic variables were associated with the perception of recycled water use, a type of water reuse similar to graywater use.

Though not researching the topic of graywater use or water reuse, Klineberg et al. (1998) found a negative correlation between age and environmental concern. Subjects who were younger and more educated had a deeper concern for the environment. This is in contrast to the finding from Liu (2006) with her finding between age and support for water reuse projects.

The observation that graywater use was high among respondents in their mid 40s to mid 60s relative to other age groups in the Berkeley sample (see Figure 13) could be because respondents in this age range experienced droughts before in California during the 1970s and have more experience using graywater. Secondly, there might also be some people in the age range, possibly in their mid 50s and older, who might be retired and thus have more time to use graywater in their homes.

Due to the inconclusive finding between age and graywater use from the current survey study and the lack of available data on age and graywater use, further research needs to be conducted to further determine the role that age plays in affecting residential graywater use. Additional research needs to be conducted to determine why younger respondents from the current study did not have a higher use of graywater than older age groups given the negative correlation found between age and environmental concern from Klineberg et al. (1998).

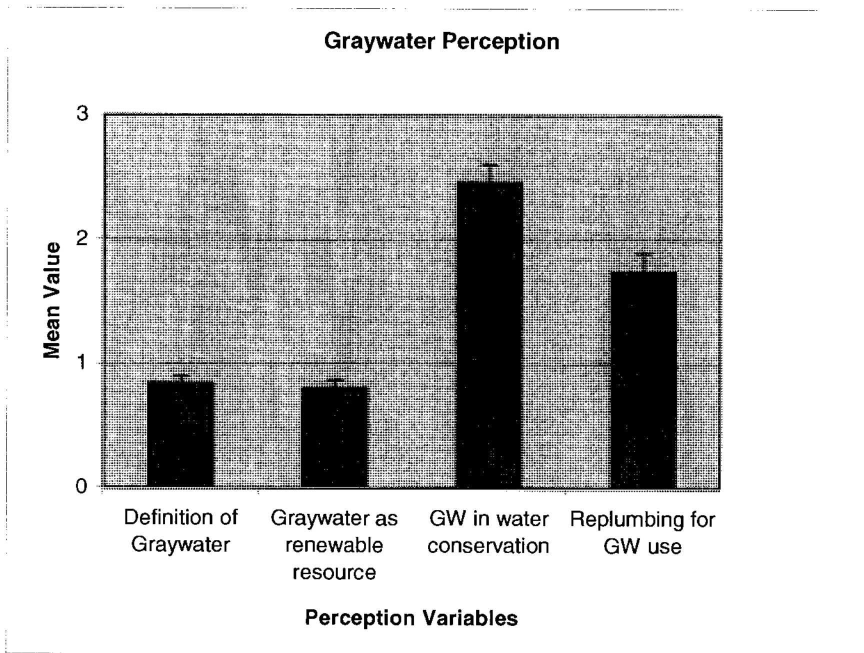

Figure 14. Perception of graywater from the Berkeley sample.

The perception of graywater and its use were quite positive in the residential survey taken from the Berkeley and Water Reuse Warriors samples. Surveyed residents generally agreed with the definition of graywater, as defined in the survey (see Figures 8 and 14). Respondents from both samples also thought graywater is a potentially renewable resource for water conservation and that it has a pretty good potential in conserving water. This positive perception of graywater led survey respondents to want to replumb their homes for graywater use (see Figures 8 and 14).

Christova-Boal et al. (1995) observed a positive, though lacking perception of graywater compared to those reported from the Berkeley and Water Reuse Warriors samples. In their survey of residents from Melbourne, just 7% of the residents were aware of the term "greywater" with only 4% having a correct understanding of the term.

In the residential graywater study by Water CASA, however, the perception of graywater use was quite discouraging and pronounced. Over 90% of the survey respondents indicated that they did not know how to use graywater. Of those who did not know how to use graywater, 30% indicated that it was due to the lack of knowledge on how to use it, in addition to the lack of information and assistance. Around 20% of the responses given for not using graywater alluded to its inconvenience, cost issues, and the general lack of time to use it. Reasons regarding the lack of use for the graywater generated and its practicality accounted for 19% of responses. Health and environmental concerns associated with graywater use accounted for 15% of responses (Little et al., 2000).

Graywater is a renewable resource and will play a crucial role in the near future, a sentiment shared by the five interviewees. It is also water reuse in its strict definition. Its many uses are well studied and documented, from irrigating non-edible plants (Whitney et al., 1999) to flushing toilets (Christova-Boal et al., 1995). However, its use must be balanced with caution due to potential risks from fecal contamination, a concern documented from various studies (Little et al., 2000; Roesner et al., 2006; Jamrah et al., n.d.). Well-planned outreach programs addressing the benefits and potential risks of graywater use are part of the plan to effectively promote its use. Graywater use is not completely effective without a set of guidelines, for example, as seen in Appendix G (Title 24, Part 5).

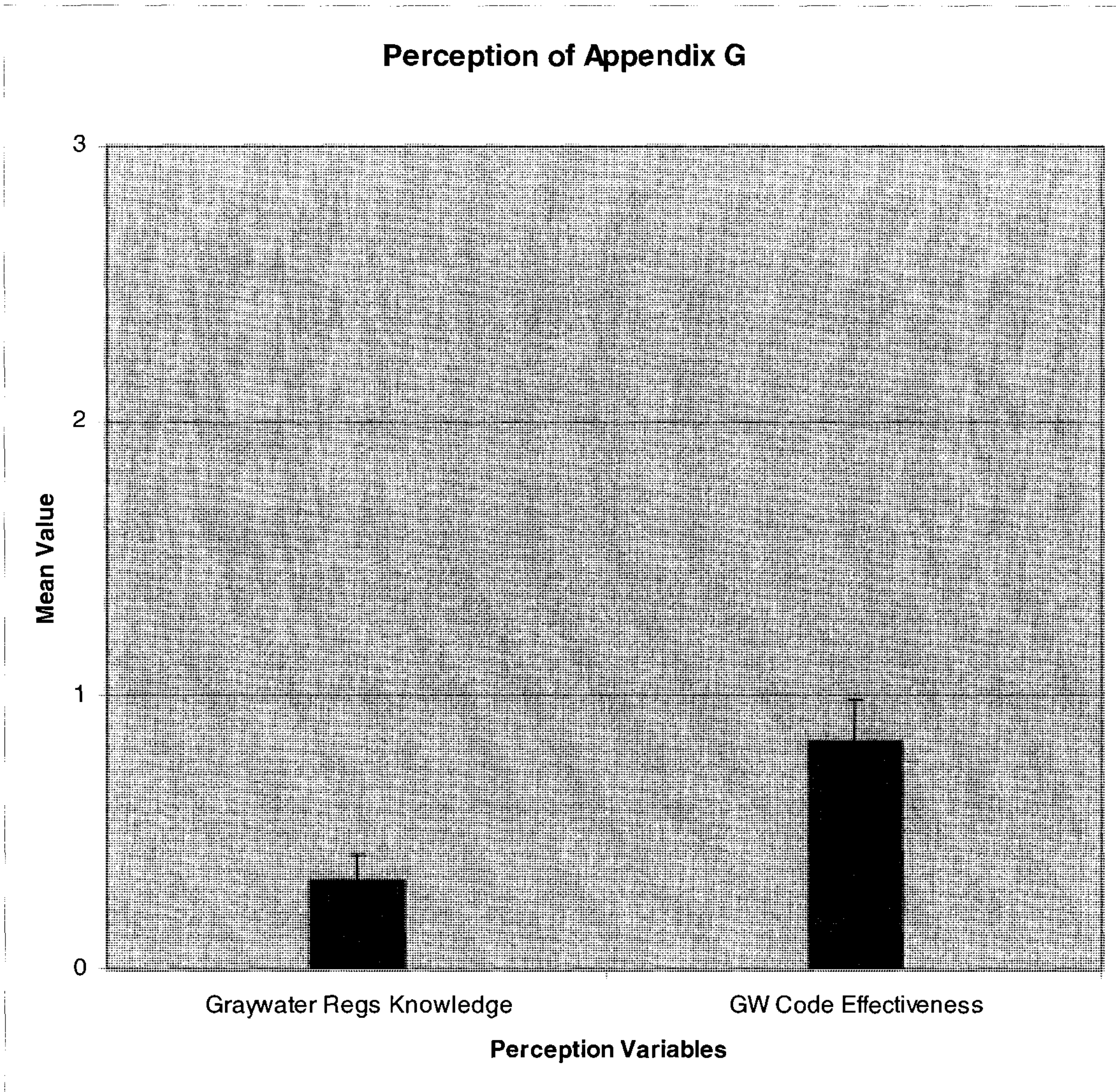

Figure 15. Perception of Appendix G (Title 24, Part 5) from the Berkeley sample.

The perception of Appendix G (Title 24, Part 5) was not positive because respondents from both samples did not know too much about it. The limited knowledge of Appendix G (Title 24, Part 5) is probably due to its verbosity, numerous requirements and overall lengthy appearance. Respondents from the Water Reuse Warriors sample, however, knew a little more about Appendix G (Title 24, Part 5) than the Berkeley sample. This is probably attributed to the influence from the NGO. In terms of effectiveness, respondents from both samples thought that Appendix G (Title 24, Part 5) was ineffective in promoting graywater use (see Figures 9 and 15), probably due to the costs associated with each step of the permitting process.

The reasons listed for Appendix G (Title 24, Part 5) being ineffective varied, but had cost as a common factor (see Appendix E), from a lack of financial incentive to construct a graywater system to a long time frame for permit approval. The observation of the permitting process in Appendix G (Title 24, Part 5) being burdensome was also corroborated by findings from Whitney et al. (1999). Interviewees from the California Department of Water Resources and East Bay Municipal Utility District also referred to the permitting process under Appendix G (Title 24, Part 5) as difficult and full of obstacles to overcome.

In regards to the Arizona regulations guiding graywater use during the Water CASA study, i.e., Appendix G under the Uniform Plumbing Code (UPC) from the International Association of International Association of Plumbing and Mechanical Officials (IAPMO), 7% of reasons given for not using graywater were for issues related to permitting and other legalities. A similar reason was also found in surveys from the Berkeley and Water Reuse Warriors samples. Reasons given by survey participants for Appendix G (Title 24, Part 5) being ineffective, like overly restrictive specifications and difficulties in obtaining a permit, seem to originate from the protection of public health advocated by state and local officials. The overprotective nature that comes from the requirements of Appendix G (Title 24, Part 5) has merit.

According to Carpenter (2008), public health is still the focus of state officials who wrote Appendix G (Title 24, Part 5). The requirement of graywater delivery systems needing to be housed underground is based on the avoidance of human and animal contact, probably due to the risk of fecal contamination (Roesner et al., 2006). Protecting public health was a challenge during the creation of Appendix G (Title 24, Part 5) because graywater was viewed like sewage, according to two public officials during the interviews (see Appendix F, Question 2), when it is not.

The public health focus of Appendix G (Title 24, Part 5) is not being questioned, rather the numerous requirements which are used to keep the focus. Four out of the five interviewees agreed that Appendix G (Title 24, Part 5) should be changed. This change could lower illicit uses of graywater and reduce the various requirements that hamper the permit for a graywater system.

Comparison of Berkeley findings with Water CASA study

The research conducted by Water CASA in 1998 is the only comprehensive study on graywater use in the United States that looked at usage in the residential setting. Though the overall sample size from the Berkeley study was smaller ($N = 169$) than the one from Water CASA ($N = 581$), the reported results on graywater use and source point to differences in climate and water use between the two regions.

The current graywater use rate in the Berkeley sample is at 16% versus the 13% graywater use rate for CASA's study from 1998 to 2000 (see Table 27). The 13%

graywater use is a rate weighted to the entire population of Tucson. Graywater use in the eight areas sampled ranged from as low as 1.5% to as high as 25% (Little et al., 2000).

Table 27

Comparison of graywater use and application data between the Berkeley sample and Water CASA study from 1998 to 2000.

	Berkeley 2008	**Water CASA 1998**
Mailed surveys	800	1983
Return rate	21%	33%
***N* sample size**	169	581
Area	Berkeley	Tucson
Graywater Use	16%	13%
		(*n* = 49)
Graywater Source (*n* = 48)	% of all reported sources	% of all reported sources
clothes washer	13%	66%
bathroom tub/shower	37%	15%
kitchen sink	44%	10%
bathroom sink	6%	5%
source to user ratio	1.4	1.2
Graywater storage (*n*)	5	2
storage location, above ground (*n*)	5	2
Graywater Application (*n* = 47)		
shade/ornamental trees	30%	32%
shrubs/rose bushes	64%	19%
grass	45%	14%
potted plants	49%	---
herb/vegetable	**30%**	4%
wildflowers	23%	---
fruit/nut trees	15%	9%
application to user ratio	2.9	1.3

Though the sample size for graywater users is comparable between the two studies, there are stark differences in the sources for graywater and the different applications for it. For the Berkeley sample, the bathroom tub/shower, kitchen and bathroom sink received higher usage than their counterparts in the 1998 CASA study (see Table 27). The reason behind the higher use of kitchen sinks for graywater in the Berkeley sample remains unclear since the current graywater survey did not ask the resident about how or why the graywater was harvested; only the source was asked. Per Appendix G (Title 24, Part 5), wastewater from kitchen sinks is not a usable graywater source. The corresponding source to user ratio is slightly higher in the Berkeley sample than Water CASA's study from 1998.

In terms of storage, there was twice as much graywater stored in the Berkeley study though both studies reported aboveground storage. The storage of graywater is of concern due to the potential for the growth of vectors like mosquitoes, which can spread diseases like the West Nile Virus.

Arizona is much hotter than California, so it is not surprising to see the percentage differences in application sites using graywater. Graywater from the Water CASA study was used mostly on shade/ornamental trees (32%) and less on leafy and more luscious green plants, like shrubs, vegetables and herbs, and grass (see Table 27).

For the Berkeley study, graywater application was more even with higher use rates on shrubs/rose bushes, potted plants, grass, and herb/vegetable gardens. The observation of graywater application on vegetable/herbs is of concern in California because it is in violation of the allowed use areas promulgated in Appendix G (Title 24, Part 5), under G13 (Health and Safety). There is also a potential for disease transmission since leafy herbs are in closer contact with the soil than other plants and trees.

When it comes to the number of applications used per graywater user, residents from the Berkeley sample were using graywater on more applications than their counterparts in the 1998 study by Water CASA. The application to user ratio for the Berkeley sample was 2.9 versus 1.3 for the Water CASA study (see Table 27). This is probably due to the relative difference in water restrictions between the two states.

Based on the startling percentage of illicit graywater use in the residential sector and soil/water quality results, reported by Water CASA from their graywater residential use study in 1998, the Arizona Department of Environmental Quality (ADEQ) rewrote their graywater code so that it could be more accommodating to the needs of residents in Arizona (V. Little, personal communication, June 20, 2006; WRRC 2006 Conference; Little 2008). Appendix G (Title 24, Part 5) for California is currently being revised under Senate Bill (SB) 1258.

CONCLUSION

Graywater use was observed to be at a current rate of 16% for the Berkeley sample and 82% for the Water Reuse Warriors sample ($N = 22$). The observed graywater use rates from both samples are also unpermitted. Reported sources of graywater from both samples came from the kitchen sink, the bathroom shower and/or tub, bathroom sink, and clothes washer. Graywater, from both samples, was used to irrigate a variety of plants and trees, but was also used to irrigate the herb and vegetable garden.

In terms of the demographic variables that were associated with graywater use, annual household income and education were determined to have statistical significance. Age was also identified as possibly associated with graywater use, but the finding is inconclusive. Respondents with lower annual household incomes were using graywater more than those with higher annual household incomes. Respondents with only bachelor's degrees were using graywater more than those with other educational levels.

Respondents from both samples had a positive view of graywater. They agreed with the definition of graywater, as stated in the residential survey. In terms of the perception of graywater, respondents from both samples believed that, in general, graywater is a potentially renewable resource to address water conservation issues. They also believed that graywater has a good potential in conserving water. When asked about replumbing their homes for graywater, respondents from both samples, in general, indicated they were interested.

The opinion on Appendix G (Title 24, Part 5) was lacking and needed to be changed. The unsatisfactory opinion of Appendix G (Title 24, Part 5) was partially due to the costs associated with the many requirements. The need to change Appendix G (Title 24, Part 5), in order to possibly help increase compliance of graywater use, was shared by most interviewees during the semi-formal interview portion of the current study.

The presence of a high, though illicit graywater use rate observed mainly in the Berkeley sample raises concerns in the public health community, but also elicits feelings of hope in light of the drought conditions Californians are currently facing. When used properly, either in the irrigation of landscape or garden, graywater can relieve the current load on our drinking water supply, thereby preserving it for potable needs. If used with careless ambition, the potential risks from fecal contamination can severely outweigh the benefits.

The finding that graywater use was higher among lower income people than those with higher incomes suggests that working class individuals are interested in using graywater. They are looking for a cheaper way to use their graywater without having to do it illegally. When graywater use was found to occur more frequently for people with only bachelor's degrees, this could be pointing to a need to reformat Appendix G (Title 24, Part 5) so that it is not too complicated to follow.

Respondents from both samples generally understood the definition of graywater from the survey. They also had a positive view of graywater, but had an unfavorable opinion of Appendix G (Title 24, Part 5). This suggests that there is public support for graywater and for the reformation of Appendix G (Title 24, Part 5).

Based on the varied determinations from survey studies on residential graywater use and perception from the Berkeley and NGO samples, the following recommendations are proposed. One of the major findings from this study was that residents with lower household incomes were using graywater more than those with higher incomes. Therefore, the costs associated with securing a legal graywater use permit under Appendix G (Title 24, Part 5) should be made more affordable. The current cost of a legal residential graywater use system in California ranges from $5,000 to $7,000, for permits and materials alone minus labor.

From the main and smaller NGO survey results, illicit residential graywater use was present in at least one city in California. Public outreach programs should be created with a goal to educate interested persons about graywater's resource conservation potential, while at the same time inform about its potential risks around the home. Since there was such a positive perception of graywater from both the Berkeley and NGO samples (see Figures 8 and 14), the public outreach sessions will be much welcomed and appreciated.

Furthermore, the outreach programs should also focus on educating the public about Appendix G (Title 24, Part 5), since most survey respondents from the Berkeley and NGO samples had little knowledge about the regulation. With the unsatisfactory perception of Appendix G (Title 24, Part 5) from both survey samples and observed graywater use rate of 16% from the Berkeley sample, California state policy makers should consider rewriting Appendix G (Title 24, Part 5) of the California Plumbing Code so that it is more accommodating to residential graywater users like Title 18 in Arizona.

The current findings suggest that the Water Reuse Warriors are influential in promoting residential graywater use and knowledge of Appendix G (Title 24, Part 5), seen in the comparison of the NGO and Berkeley samples (see Figure 9 versus Figure 15). The respondents from the NGO sample study knew more about Appendix G (Title 24, Part 5) than their counterparts in the Berkeley sample. With this observation, the Water Reuse Warriors and other NGOs like it should have a more official role as stakeholders in contributing to solutions for addressing different water conservation issues throughout California. Currently, the Greywater Alliance, a committee made up of professionals from the public and the government and formed ad hoc to deal with residential graywater use and other related water conservation issues, is addressing how to best rewrite Appendix G (Title 24, Part 5) so that it can better accommodate residential graywater use in California (Allen et al., 2008).

Though graywater has been and continues to be relied on to irrigate ornamental plants, gardens, landscapes, and flush toilets, it is not the "silver bullet" used to solve problems associated with water conservation. It is one tool among the vast array of tools currently available. The current water supply concerns in California, across parts of the United States, and throughout the world are best addressed and solved by combining water reuse technologies with traditional water conservation techniques, like watering the lawn in the evening on odd days of the week during the summer.

Even with all the technology, science, and policies, water conservation will not be fully achieved without a change in the unrealistic perception of the unlimited supply of natural resources. Society seems to be trapped in a social paradigm where the belief is one of a bottomless natural resource pit, a need for growth, and incessant progress (Albrecht, Bultena, Hoiberg, and Nowak 1982). This type of perception evokes carelessness given the dire water supply situation in California, for example. The paradigm affects society's perception and in turn affects its outward behavior. An unfortunate part of our culture is that society will not modify its behavior until there is sudden change in the form of a disaster. Maybe society's wasteful behavior will change, maybe not. But one thing is certain and it is "we never know the worth of water till the well is dry" (Thomas Fuller).

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Interviews/E-mail contact:

E-mail:

C. Dundon, Contra Costa Water District (January 2009)

C. Foresythe*, East Bay Municipal Utility District, (October 2007)

J. Rowland, Department of Housing and Community Development (December 2008)

M. Smith*, Water Reuse Warriors (July 2007-December 2008)

S. Eching, Department of Water Resources (July 2008)

Semi-structured interviews:

C. Foresythe* East Bay Municipal Utility District. February 1, 2008.

C. Mortensen* City of Berkeley. March 10, 2008.

L. Myers* EcoHouse. March 24, 2008.

M. Smith* Water Reuse Warriors. March 1, 2008.

R. Corvelle* Department of Water Resources. July 7, 2008.

***pseudonyms used for interviewee to protect the identity of information source per IRB protocol**

APPENDIX A

Budget

Postage	
800 surveys (return prepaid postage included)	**$656**
Printing	
Kinko's 800 surveys at 2 pages per survey; double sided 1600 pages, single sided (implied consent form and cover letter)	**$300**
Envelopes	
1,000 plain envelopes (#10) 1,000 plain envelopes (#63/4)	**$35**
Labels	
Kinko's (1,600 labels; printing and label cost)	**$110**
Other	
Haines Criss-Cross Directory, Alameda County (CD ROM)	**$585**
Total	**$1,686**

APPENDIX B

San José State UNIVERSITY

RESIDENTIAL GRAYWATER USE SURVEY

California is currently facing a formidable challenge in meeting current and future water resource needs. Your responses in this survey regarding graywater, its use, and your perception of its current regulations will help in forming and changing current and future water conservation policies. Your responses are anonymous and **will be kept confidential** and secured after the results are compiled and the study is complete. Thank you very much for your cooperation.

1. Are you?
   ( ) Male ( ) Female

2. What is your age?
   ( ) 18-24 ( ) 45-54 ( ) 75-84
   ( ) 25-34 ( ) 55-64 ( ) 85 or Over
   ( ) 35-44 ( ) 65-74

3. With which ethnic background do you identify?
   ( ) African American or black ( ) Latino or Hispanic
   ( ) Asian or Pacific Islander ( ) Other: ______________________________
   ( ) Euro-American or white

4. Please check the highest level of education you completed:
   ( ) Some High School ( ) College (Bachelor Degree)
   ( ) High School ( ) Graduate Degree (MBA, MA, etc.)
   ( ) Some College ( ) Doctorate (MD, PhD, etc.)

5. What is your estimated annual household income?
   ( ) Less than $30,000 ( ) $30,000 to $40,000
   ( ) $40,000 to $50,000 ( ) $50,000 to $60,000
   ( ) $60,000 to $70,000 ( ) $70,000 to $80,000
   ( ) $80,000 to $90,000 ( ) $90,000 and above

Did You Know? Graywater is water that is untreated from your bathroom sink, shower area, kitchen sink (vegetable wash water), and washing machine.
Yes ( ) No ( )

6. Have you ever used graywater on your current property or residence (i.e., watering lawn, plants)?
   ( ) Yes, currently ( ) No (**If No, please proceed to Question# 12**).

   If Yes, how long have you been using it and why?________________________________
   ____

   ( ) Yes, in the past, but not now and approximately how much?

Reason:____

7. From which sources do/did you get graywater? (check all that apply)
   ( ) washing machine ( ) kitchen sink (non-greasy wash water only)
   ( ) bathroom sink ( ) bathroom tub/shower

8. Do/Did you store any of your graywater? ( ) Yes ( ) No

   if Yes, is/was it stored above or below ground?
   ( ) above ground ( ) below ground
   if Yes, what is/was your storage volume? ____ gallons (approx.)

9. Where is/was the graywater being used? (check all that apply)
   ( ) bare dirt ( ) shrubs/rose bushes
   ( ) lawn ( ) potted plant
   ( ) shade/ornamental trees ( ) vegetable/herb garden
   ( ) fruit/nut trees ( ) compost
   ( ) wildflowers/perennials ( ) Other ________________________________

10. Is/Was your home plumbed for using graywater? **(Your response will be kept confidential).**
    ( ) Yes ( ) No

11. Is/Was your home permitted by the local government to use graywater? **(Your response will be kept confidential).**
    ( ) Yes ( ) No

12. How much do you know about the State's graywater policy under the California Plumbing Code?

( ) Nothing ( ) Very little
( ) Some information ( ) A Great Deal

(If "Nothing", go to question #16).

13. How did you learn about California's graywater policy?

( ) A friend ( ) Self-Study [journals, newspapers, online]
( ) Local Government ( ) Other______________________

14. How would you rate the California Plumbing Code's effectiveness in promoting graywater use?

( ) Don't Know ( ) Not Effective
( ) Somewhat Effective ( ) Very Effective

15. In your view, which parts of the California Plumbing Code on graywater use may make it ineffective in promoting graywater use?

( ) Don't Know
( ) Fees [permits, plan checks, contractor work, etc.]
( ) Inspections and Tests [groundwater, soil, surveying, etc.]
( ) Other____
( ) None, all parts are effective

16. Did you know, before this survey, that graywater is a potential renewable resource for water conservation?

( ) Yes ( ) No **If Yes, where did you learn about it?**____________________

17. To what extent, in your opinion, can graywater use contribute to conserving water?

( ) Don't Know ( ) Not At All ( ) A Little/Some ( ) A Great Deal/ A lot

18. Which of the following best describes your level of interest in replumbing your home for graywater use?

( ) Not at all ( ) Somewhat Interested
( ) Interested ( ) Very Interested

Thank you for completing this survey! Please return the survey in the smaller envelope provided by March 15, 2008.

APPENDIX C

Semi-structured Interview Questions

1. What is the history behind the current graywater regulations in California?
2. Were there challenges in forming the current graywater regulations?
3. Who are the major stakeholders in graywater use?
4. Does public perception have a role in shaping the graywater regulations in California? For example, do the Water Reuse Warriors and their work have an influence in causing a change to the current graywater regulations?
5. What is your opinion of the current graywater regulations for California?
6. Do you see graywater use playing a role in water conservation in California in the future?

APPENDIX D

Coding Scheme for SPSS Analyses

Gender:

Male= 1
Female= 2

Age:

Young Adult to Middle Age= 1
Middle Age to Senior= 2
Senior= 3

Ethnicity:

African American or black= 1
Asian/Pacific Islander= 2
Euro-American or white= 3
Latino or Hispanic= 4
Other= 5

Education:

Not bachelor degree= 0
Bachelor degree (only)= 1

Annual Household Income:

Less than $30,000 to $40,000= 1
$40,000 to $60,000= 2
$60,000 to $80,000= 3
$80,000 to $90,000 and above= 4

GW definition:

No= 0
Yes= 1

GW Use:

0= Never used
1=Current and past use
GW source:

Not used= 0
Used= 1

Washing machine (GW source#1)= 0,1
Bathroom sink (GW source #2)= 0,1
Kitchen sink (non-greasy wash water #3)= 0,1
Bathroom/tub shower (GW source)= 0,1

GW storage:

No= 0
Yes= 1
Above ground= 2
Below ground= 3

GW apply:

Not used= 0
Used= 1

Bare dirt (#1)
Lawn (#2)
Shade/ornamental trees (#3)
Fruit/nut trees (#4)
Wild flowers/perennials (#5)
Shrubs/rose brushes (#6)
Potted plants (#7)
Vegetable/herb garden (#8)
Compost (#9)
Other (GW apply)

GW plumbing:

No= 0
Yes= 1

GW permit:

No= 0
Yes= 1

GW Regs knowledge:

Nothing= 0
Very little= 1
Some information= 2
A Great Deal= 3

GW Regs learn:

A friend= 1
Local government= 2
Self study= 3
Other= 4
Self, Other= 5
Local, Other= 6
Friend, Other= 7
Local Government, Friend, Self= 8

GW code effectiveness:

Don't Know= 0
Not Effective= 1
Somewhat Effective=2
Very Effective= 3

GW code Ineffective:

Don't Know= 0
Fees (permits, plan checks, contractor work, etc.)= 1
Inspections and tests (groundwater, soils, surveying, etc.)= 2
Other= 3
None, all parts are effective= 4
Fess and Inspections= 5
Fees and Other= 6
Inspections and Other= 7
Fees, Inspections, and Other= 8

GW renewable:

No= 0
Yes= 1

GW as conservation:

Don't know= 0
Not At All= 1
A little/Some= 2
A Great Deal/ A lot= 3

GW home plumbing desire:

Not at all= 0
Somewhat interested= 1
Interested= 2
Very Interested= 3

APPENDIX E

Frequency Tables from SPSS

Total surveys sent: 800
Completed surveys returned: 169

Demographics:

Gender		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	65	39	39	39
	Female	103	61	61	100
	Total	168	99	100	
Missing	System	1	1		
Total		169	100		

	Ethnicity	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	African American or Black	2	1	1	1
	Asian or Pacific Islander	15	9	9	10
	Euro-American or White	145	86	87	98
	Latino or Hispanic	3	2	2	99
	Other	1	1	1	100
	Total	166	98	100	
Missing	System	3	2		
Total		169	100		

Statistics		
Age		
N	Valid	169.00
	Missing	.00
Mean		4.36
Median		4.00
Std. Deviation		1.28
Variance		1.65
Minimum		1.00
Maximum		7.00
Percentiles	25	3.00
	50	4.00
	75	5.00

	Age	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	18-24 yrs old	1	1	1	1
	25-34 yrs old	8	5	5	5
	35-44 yrs old	41	24	24	30
	45-54 yrs old	37	22	22	52
	55-64 yrs old	52	31	31	82
	65-74 yrs old	21	12	12	95
	75-84 yrs old	9	5	5	100
	Total	169	100	100	

Education		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	High School	3	2	2	2
	Some College	10	6	6	8
	College (Bachelor Degree)	65	39	39	46
	Graduate Degree (MBA, MA, etc.)	59	35	35	82
	Doctorate (MD, PhD, etc.)	31	18	19	100
	Total	168	99.4	100	
Missing	System	1	1		
Total		169	100		

Annual Household Income

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than $30,000	7	4.1	4.3	4.3
	$30,000-$40,000	10	5.9	6.2	10.5
	$40,000-$50,000	12	7.1	7.4	17.9
	$50,000-$60,000	14	8.3	8.6	26.5
	$60,000-$70,000	8	4.7	4.9	31.5
	$70,000-$80,000	25	14.8	15.4	46.9
	$80,000-$90,000	4	2.4	2.5	49.4
	$90,000 and above	82	48.5	50.6	100.0
	Total	162	95.9	100.0	
Missing	System	7	4.1		
Total		169	100.0		

Graywater Use:

Graywater Use		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	118	70	71	71
	Yes, currently	27	16	16	87
	Yes, in the past, but not now	22	13	13	100
	Total	167	99	100	
Missing	System	2	1		
Total		169	100		

Graywater Storage		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	above ground	5	3	100	100
Missing	System	164	97		
Total		169	100		

Graywater Perception:

	Definition of Graywater	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	27	16	16	16
	Yes	142	84	84	100
	Total	169	100	100	

Replumbing Home for Graywater Use		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	21	12	12	12
	Somewhat Interested	47	28	28	40
	Interested	56	33	33	73
	Very Interested	45	27	27	100
	Total	169	100	100	

Graywater as Renewable Resource Pre Survey		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	33	20	20	20
	Yes	135	80	80	100
	Total	168	99	100	
Missing	System	1	1		
Total		169	100		

Potential of Graywater in Water Conservation		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Don't Know	17	10	10	10
	A Little/Some	40	24	24	34
	A Great Deal/A lot	111	66	66	100
	Total	168	99	100	
Missing	System	1	1		
Total		169	100		

Perception of Appendix G (Title 24, Part 5):

Knowledge of Graywater Regs in Appendix G (Title 24, Part 5)		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Nothing	126	75	75	75
	Very Little	29	17	17	92
	Some Information	13	8	8	100
	Total	168	99	100	
Missing	System	1	1		
Total		169	100		

Source of Graywater Regs Knowledge in Appendix G (Title 24, Part 5)		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Friend	2	1	5	5
	Local government	1	1	2	7
	Self study (e.g., journals, newspapers, online)	22	13	54	61
	Other	11	7	27	88
	Self Study, Other	1	1	2	90
	Local Government, Other	2	1	5	95
	Friend, Other	1	1	2	98
	Friend, Local government, Self-study	1	1	2	100
	Total	41	24	100	
Missing	System	128	76		
Total		169	100		

Graywater Code Effectiveness		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Don't Know	9	5	21	21
	Not Effective	31	18	74	95
	Somewhat Effective	2	1	5	100
	Total	42	25	100	
Missing	System	127	75		
Total		169	100		

	Source of Graywater Code Ineffectiveness	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Don't Know	25	15	60	60
	Fees (permits, plan checks, contractor work, etc.)	5	3	12	71
	Other	3	2	7	79
	fees and inspections	6	4	14	93
	fees and Other	1	1	2	95
	Fees, inspections, other	2	1	5	100
	Total	42	25	100	
Missing	System	127	75		
Total		169	100		

Graywater Source:

Source washing machine

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	washing machine, not used	45	26.6	83.3	83.3
	washing machine, used	9	5.3	16.7	100.0
	Total	54	32.0	100.0	
Missing	System	115	68.0		
Total		169	100.0		

Source bathroom sink

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	bathroom sink, not used	50	29.6	92.6	92.6
	bathroom sink, used	4	2.4	7.4	100.0
	Total	54	32.0	100.0	
Missing	System	115	68.0		
Total		169	100.0		

Source bath tub/shower

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	bath tub/shower, not used	29	17.2	53.7	53.7
	bath tub/shower, used	25	14.8	46.3	100.0
	Total	54	32.0	100.0	
Missing	System	115	68.0		
Total		169	100.0		

Source kitchen sink

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	kitchen sink, not used	24	14.2	44.4	44.4
	kitchen sink, used	30	17.8	55.6	100.0
	Total	54	32.0	100.0	
Missing	System	115	68.0		
Total		169	100.0		

Graywater Application:

Apply bare dirt

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	apply bare dirt, no	47	27.8	87.0	87.0
	apply bare dirt, yes	7	4.1	13.0	100.0
	Total	54	32.0	100.0	
Missing	System	115	68.0		
Total		169	100.0		

Apply lawn

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	apply lawn, no	33	19.5	61.1	61.1
	apply lawn, yes	21	12.4	38.9	100.0
	Total	54	32.0	100.0	
Missing	System	115	68.0		
Total		169	100.0		

Apply shade/ornamental trees

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	apply shade/ornamental trees, no	40	23.7	74.1	74.1
	apply shade/ornamental trees, yes	14	8.3	25.9	100.0
	Total	54	32.0	100.0	
Missing	System	115	68.0		
Total		169	100.0		

Apply fruit/nut trees

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	apply fruit/nut trees, no	47	27.8	87.0	87.0
	apply fruit/nut trees, yes	7	4.1	13.0	100.0
	Total	54	32.0	100.0	
Missing	System	115	68.0		
Total		169	100.0		

Apply wildflowers

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	apply wildflowers, no	43	25.4	79.6	79.6
	apply wildflowers, yes	11	6.5	20.4	100.0
	Total	54	32.0	100.0	
Missing	System	115	68.0		
Total		169	100.0		

Apply shrubs/rose bushes

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	apply shrubs/rose bushes, no	24	14.2	44.4	44.4
	apply shrubs/rose bushes, yes	30	17.8	55.6	100.0
	Total	54	32.0	100.0	
Missing	System	115	68.0		
Total		169	100.0		

Apply potted plant

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	apply potted plant, no	31	18.3	57.4	57.4
	apply potted plant, yes	23	13.6	42.6	100.0
	Total	54	32.0	100.0	
Missing	System	115	68.0		
Total		169	100.0		

Apply vegetable/herb garden

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	apply vegetable/herb garden, no	40	23.7	74.1	74.1
	apply vegetable/herb garden, yes	14	8.3	25.9	100.0
	Total	54	32.0	100.0	
Missing	System	115	68.0		
Total		169	100.0		

Apply compost

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	apply compost, no	50	29.6	92.6	92.6
	apply compost, yes	4	2.4	7.4	100.0
	Total	54	32.0	100.0	
Missing	System	115	68.0		
Total		169	100.0		

Apply Other

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	apply other, no	50	29.6	92.6	92.6
	apply other, yes	4	2.4	7.4	100.0
	Total	54	32.0	100.0	
Missing	System	115	68.0		
Total		169	100.0		

Education and Graywater Use:

Cross tabulation between Education and Graywater Use (Past and Present)

Education	Count and Percentage	dichotomized gw use check Never Used	Current and Past Use	Total
High School	Count	2	1	3
	% within Education	67	33	100
Some College	Count	8	2	10
	% within Education	80	20	100
College (Bachelor Degree)	Count	39	25	64
	% within Education	61	39	100
Graduate Degree (MBA, MA, etc.)	Count	46	13	59
	% within Education	78	22	100
Doctorate (MD, PhD, etc.)	Count	22	8	30
	% within Education	73	27	100
Total	Count	117	49	166
	% within Education	70	30	100

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.964	4	0.291
Likelihood Ratio	4.950	4	0.293
Linear-by-Linear Association	1.018	1	0.313
N of Valid Cases	166		

Graywater Guerilla Data Set (Frequency Tables):

Surveys sent: 30
Surveys received: 22

Demographics:

Age

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	18-24 yrs old	3	13.6	13.6	13.6
	25-34 yrs old	11	50.0	50.0	63.6
	35-44 yrs old	4	18.2	18.2	81.8
	45-54 yrs old	3	13.6	13.6	95.5
	55-64 yrs old	1	4.5	4.5	100.0
	Total	22	100.0	100.0	

Ethnicity

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Asian or Pacific Islander	1	4.5	4.5	4.5
	Euro-American or White	15	68.2	68.2	72.7
	Latino or Hispanic	2	9.1	9.1	81.8
	Other	4	18.2	18.2	100.0
	Total	22	100.0	100.0	

Education

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	High School	1	4.5	4.5	4.5
	Some College	3	13.6	13.6	18.2
	College (Bachelor Degree)	13	59.1	59.1	77.3
	Graduate Degree (MBA, MA, etc.)	5	22.7	22.7	100.0
	Total	22	100.0	100.0	

Annual Household Income

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than $30,000	13	59.1	59.1	59.1
	$30,000-$40,000	1	4.5	4.5	63.6
	$40,000-$50,000	3	13.6	13.6	77.3
	$60,000-$70,000	1	4.5	4.5	81.8
	$70,000-$80,000	1	4.5	4.5	86.4
	$80,000-$90,000	1	4.5	4.5	90.9
	$90,000 and above	2	9.1	9.1	100.0
	Total	22	100.0	100.0	

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	7	31.8	31.8	31.8
	Female	15	68.2	68.2	100.0
	Total	22	100.0	100.0	

Graywater Use:

Graywater Use (dichotomized)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never Used	3	13.6	13.6	13.6
	Either Used in past or currently using	19	86.4	86.4	100.0
	Total	22	100.0	100.0	

Graywater Use (not dichotomized)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never used	3	13.6	13.6	13.6
	Past usage	1	4.5	4.5	18.2
	Current usage	18	81.8	81.8	100.0
	Total	22	100.0	100.0	

Ineffectiveness of Appendix G (Title 24, Part 5):

Source of Graywater Code Ineffectiveness

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Don't Know	9	40.9	45.0	45.0
	fees and inspections	6	27.3	30.0	75.0
	fees and Other	2	9.1	10.0	85.0
	Fees, inspections, other	3	13.6	15.0	100.0
	Total	20	90.9	100.0	
Missing	System	2	9.1		
Total		22	100.0		

Graywater Storage:

Graywater storage

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	14	63.6	73.7	73.7
	Yes	5	22.7	26.3	100.0
	Total	19	86.4	100.0	
Missing	System	3	13.6		
Total		22	100.0		

Graywater storage location

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	above ground	1	4.5	25.0	25.0
	below ground	2	9.1	50.0	75.0
	above and below ground	1	4.5	25.0	100.0
	Total	4	18.2	100.0	
Missing	System	18	81.8		
Total		22	100.0		

APPENDIX F

Interview Findings Summary

Semi-structured Interview Questions

1. What is the history behind the current graywater regulations in California?
2. Were there challenges in forming the current graywater regulations?
3. Who are the major stakeholders in graywater use?
4. Does public perception have a role in shaping the graywater regulations in California? For example, do the Water Reuse Warriors and their work have an influence in causing a change to the current graywater regulations?
5. What is your opinion of the current graywater regulations for California?
6. Do you see graywater use playing a role in water conservation in California in the future?

As part of my study on the perception on graywater and the effects on its use, I interviewed 5 representatives from different government and grassroots organizations involved in water conservation with a specific focus on graywater use. I developed the informal interview questionnaire with the mindset of starting with the history of Appendix G (Title 24, Part 5), specifically on why it was created, progressing to stakeholders and challenges in forming the regulation, and ending with the perception of Appendix G (Title 24, Part 5) and the role of graywater in addressing water conservation issues. Per conditions of anonymity detailed in the IRB approved form "Agreement to Participate in Research" (See Appendix G), the identities of the interviewees are not revealed.

What is the history behind the current graywater regulations in California?

On the history behind the formation of Appendix G (Title 24, Part 5), most of those interviewed indicated that graywater use started as a result of drought which started during the 1970's; graywater use progressed into the late 80's and the early 90's, and well into today. According to an official from East Bay Municipal Utility District (EBMUD), there were no adopted regulations on graywater use in California until 1992. The EBMUD official also mentioned that from 1986-1987 there was more interest in codifying a graywater code.

Were there challenges in forming the current graywater regulations?

In general, when a new regulation is being developed, there are challenges from and for stakeholders involved. Appendix G (Title 24, Part 5) states that wastewater from kitchen sinks is not considered graywater. One interviewee thought that kitchen sink water should be allowed in Appendix G (Title 24, Part 5) as graywater. This same person pointed out that Appendix G (Title 24, Part 5) is not presented simply like the graywater guidelines for Arizona, found in Title 18. It provides simple guidelines to use graywater in a safe manner unlike Appendix G (Title 24, Part 5).

In terms of the way Appendix G (Title 24, Part 5) is written, the calculations, e.g., percolation tests, are "daunting to the average person." The EBMUD official pointed out that while water utilities generally support graywater use, health departments are cautious and focusing on its impact on the environment and the public. One challenge in graywater was its application. Which method makes most sense in terms of feasibility and safety? The answer was and still is subsurface application of graywater with no ponding or spraying allowed.

One official from the Department of Water Resources said that policy makers were afraid of graywater when they were writing Appendix G (Title 24, Part 5); they thought it was comparable to sewage. The perception of graywater as not being compared with sewage or the like was definitely a challenge for those writing Appendix G (Title 24, Part 5). Because of this perception, local health departments were wary of graywater use and the consequence of that is local agencies not allowing its use. Perception, according to the DWR official, plays a vital role in the acceptance of graywater and its use.

From an NGO perspective, a representative from the Water Reuse Warriors said that "getting change is a challenge," in terms of writing use regulations for something that was compared to sewage. Since Appendix G (Title 24, Part 5) was written at the "state level," there was no input from the general public included in the writing of the regulation. This itself is a challenge for potential users of graywater because the code was not written with their interest in mind.

Who are the major stakeholders in graywater use?

All five interviewees had similar responses on the stakeholders involved in graywater use, but each had a slightly different response due to his/her own area of responsibility and expertise. The major stakeholders in graywater use mentioned were water utilities, health departments or county health agencies, planning departments, green building advocates, non governmental organizations (NGOs), lobbying groups, plumbers, and residential users.

Does public perception have a role in shaping the graywater regulations in California? For example, do the Water Reuse Warriors and their work have an influence in causing a change to the current graywater regulations?

According to an official from DWR, there would be more support in the legislature for an amendment of Appendix G (Title 24, Part 5) if more people were using graywater. However, water conservation is difficult to practice when people who perceive water conservation as a necessity see their neighbors waste water, especially during outdoor activities. To address this issue, the DWR official suggested more education to change the perception. DWR does not, however, advocate the type of work the Water Reuse Warriors are doing to promote graywater.

A representative from EcoHouse in Berkeley, however, sees the work of the Water Reuse Warriors as definitely influencing the movement to change Appendix G (Title 24, Part 5). They are influencing this change by helping to promote SB 1258, the senate bill that seeks to expand the use of graywater in the residential area. In terms of perception, the Ecohouse representative said that the public is looking at their respective cities for leadership and accountability in education on graywater and its use.

From the perspective of the EBMUD official, there is a "large group of people" showing interest in water conservation by directing graywater to their landscape. However, this desire to use graywater is being hindered by the current steps required by Appendix G (Title 24, Part 5) to obtain a permit for using graywater in the home. The biggest cost, according to the EBMUD official, is the permitting process and it is quite "onerous."

From the viewpoint of a representative from the Water Reuse Warriors, some people tend to use graywater illegally knowing they will not obtain a permit, while others want to follow the permitting process. If there is an outcry from the public to change the current way graywater use is regulated in the residential area, government officials might be pressured into changing Appendix G (Title 24, Part 5). Public perception of graywater use is not only influenced by the Water Reuse Warriors; the media has an important role in shaping perception. The Water Use Warrior representative said that the media has led the public to believe that they are "breaking the law."

According to a Berkeley city official, the Water Reuse Warriors are doing a "disfavor" to the public by not following Appendix G (Title 24, Part 5) when using and promoting graywater. On public perception, the city official said that it has "influence in shaping what is green these days."

What is your opinion of the current graywater regulations for California?

Four out of the five interviewees noted that Appendix G (Title 24, Part 5) should to be changed, except for the Berkeley city official who said that the graywater code is "pretty straight forward and detailed." On the specifics of Appendix G (Title 24, Part 5), the Berkeley official said that it requires that certain valves be installed to prevent graywater discharging into the potable water lines. In addition, there needs to be sufficient distance between homes in order to prevent graywater from discharging into neighboring homes causing erosion, landslides, ponding in basements, and nuisance.

The official from EBMUD said that Appendix G (Title 24, Part 5) is not effective in promoting graywater use because "no one is following [it] legally." In the last five years, the permit and planning office in Alameda and Contra Costa counties have received only a handful of permit applications for graywater, according to the EBMUD official. Delivery of graywater to the landscape, according to the EBMUD official, is the "onerous" part.

Going into specifics on Appendix G (Title 24, Part 5), the EBMUD official referred to complications, e.g., how to determine valve placement and operation, arising from connecting graywater systems in homes with existing irrigation systems while following the prescriptions of Appendix G (Title 24, Part 5). Furthermore, dual drain lines that help facilitate graywater delivery from the home to the backyard are best suited for homes with a raised foundation rather than slab foundations, due to the high cost of retrofitting the latter. The DWR official also voiced the same sentiment of Appendix G (Title 24, Part 5) needing change by noting that there are "too many obstacles" in Appendix G (Title 24, Part 5) to get a graywater system approved.

The representative from the Ecohouse noted that Appendix G (Title 24, Part 5) was written for a specific group in the population, namely plumbers and those who understand all the technical jargon. It is an appendix for the "avid," and therefore presents no real incentive to use graywater for the average homeowner.

The spokesperson for the Water Reuse Warriors noted that Appendix G (Title 24, Part 5) needs to be changed and suggested the following areas of the code that need to be modified: (1) battery of tests (e.g., percolation test) to be performed only by licensed professionals, (2) discharge restrictions which require a deeper depth for graywater release, and (3) "impossible" restrictions; for example, the cost of drilling a well just to find the groundwater table.

Do you see graywater use playing a role in water conservation in California in the future?

On this note, all five interviewees agreed that graywater use plays a key role in water conservation for California in the future. The Berkeley city official said that the role of graywater in conservation will increase in the future and that water, as a natural resource, will become a highly sought after commodity like oil is today.

For the EBMUD official, graywater will play an important role in new construction and will be "an insurance policy" for residential landscapes during a drought. However, the EBMUD official added that with its advantages, graywater will never really be "huge for its use." He said reusing graywater requires a lot of work and when the cost of water in a year with normal precipitation, there is difficulty in justifying graywater use and all the labor involved. The EBMUD official went on to add that graywater is only useful during the dry summer months because there is plenty of water during the winter.

Besides seasonal uses of graywater, the amount generated depends on the number of people in the household. Smaller households would generate less graywater than one with a larger number. Furthermore, graywater, as a renewable resource, might have competition from reclaimed and desalinated water when their technology advances.

The DWR official noted that graywater should be combined with rainwater harvesting in certain parts California to address water shortage issues. Graywater should be used in the summer months while rainwater should be harvested in the winter.

A spokesperson for the Water Reuse Warriors said that graywater will definitely have a role in conserving water in CA for the future and that graywater workshops are filling up with interested people. According to the representative from the Ecohouse, graywater has a role in water conservation in California, especially when its population will double in the next 25 to 30 years.

APPENDIX G

IRB Protocol Documents

Agreement to Participate in Research

Responsible Investigator: Chung Mong Khong
Title of Protocol: Perception of Graywater Use in Berkeley, California

You have been asked to participate in a study investigating public attitude and knowledge of residential graywater use and policy for the single family homeowner. The results from this study will help policy makers at the city and state level to develop and reevaluate, if needed, new and current graywater use policies.

You will be given a survey that contains a series of questions regarding your basic demographic background, your attitude and knowledge about graywater use on your property. Finally, you will be asked about your awareness and opinion of the current graywater use guidelines/regulations in California. Responses you provide are anonymous and **will remain confidential**, and if you feel uneasy about any question, you can choose not to answer it.

Although the results of this study may be published, no information that could identify you will be included.

Questions about this research may be addressed to Chung Mong Khong at ckhong2025@gmail.com. Complaints about the research may be presented to Dr. Rachel O'Malley, Associate Professor and Chair of the Department of Environmental Studies, at (408) 924-5424 or at romalley@sjsu.edu. Questions about research subjects' rights, or research-related injury may be presented to Pamela Stacks, Ph.D., Associate Vice President for Graduate Studies and Research, at (408) 924-2480.

No service of any kind, to which you are otherwise entitled, will be lost or jeopardized if you choose to "not participate" in the study.

Your consent is being given voluntarily. You may refuse to participate in the entire study or in any part of the study. If you decide to participate in the study, you are free to withdraw at any time without any negative effect on your relations with San Jose State University.

Please keep this copy for your own records. By agreeing to participate in this study, it is implied that you have read and understood the above information.

Dear Berkeley Resident,

The Environmental Studies Department at San Jose State University invites you to participate in a survey of graywater perception and use in your city. The results of this study will increase our understanding of the public attitudes towards graywater and water conservation. Our objective is to use our findings to help policy makers re-evaluate existing graywater guidelines and regulations. Attached is a brief survey, which takes approximately 5 minutes to complete. You need to be an adult (18 years old and older) homeowner to participate in this study.

Your participation is voluntary. Choosing not to participate in this study, or in any part of this study, will not affect your relations with San Jose State University. You have the right to not answer questions you do not wish to answer. When you have finished the survey, please fold and place in the smaller, self-addressed and stamped envelope before mailing.

There are questions in the survey that will ask for personal information (i.e., age, household income, education, and permit-related questions). This survey is anonymous. **Your responses will be kept confidential for the duration of the study and destroyed when the study is complete.**

The results of this study may be published, but any information that could result in your identification will remain confidential.

If you have questions about this study, we will be happy to talk with you. We can be reached at ckhong2025@gmail.com. Complaints about the research may be presented to Dr. Rachel O'Malley, Associate Professor and Chair of the Department of Environmental Studies, at (408) 924-5424 or at romalley@sjsu.edu. Questions about research a subjects' rights, or research-related injury may be presented to Pamela Stacks, Ph.D., Associate Vice President, Graduate Studies and Research, at (408) 924-2480.

Sincerely,

Chung Mong Khong	Katherine Cushing, Ph.D.
M.S. and Principal Investigator	Asst. Professor of Environmental Studies

Agreement to Participate in Research

Responsible Investigator: Chung Mong Khong
Title of Protocol: Perception of Graywater Use in Berkeley, California

You have been asked to participate in a study investigating public attitude and knowledge of residential graywater use and policy for the single family homeowner. The results from this study will help policy makers at the city and state level to develop and reevaluate, if needed, new and current graywater use policies.

You are participating in an informal interview that contains a series of questions regarding California's graywater policy history, challenges in graywater policy formation, role of public perception in graywater policy enforcement, and your attitude of the current California graywater policy and graywater use in the future in Berkeley and the State of California. The interview will be tape recorded.

Although the results of this study may be published, no information that could identify you will be included.

Questions about this research may be addressed to Chung Mong Khong at (408)-386-7367. Complaints about the research may be presented to Dr. Rachel O'Malley, Associate Professor and Chair of the Department of Environmental Studies, at (408) 924-5424 or at romalley@sjsu.edu. Questions about research subjects' rights, or research-related injury may be presented to Pamela Stacks, Ph.D., Associate Vice President for Graduate Studies and Research, at (408) 924-2480.

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