

WHITE PAPER

ON

GRAYWATER

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prepared by

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The words “recycling” and “reclamation”, “recycled” and “reclaimed”, and their derivatives are used synonymously and interchangeably in this document—recognizing the common use of each set of words in different regions of the country and the world.

EXECUTIVE SUMMARY

- Graywater reuse is viewed by the green-leaning layperson as the panacea for saving a thirsty world from water scarcities caused by population explosion, global warming, and persistent droughts.
- Graywater is seen by society's public health guardians (including the water utilities) as a threat to health and safety of the users themselves and their neighbors.

Neither of these caricatures of graywater is accurate, although an element of truth resides in each. In fact, graywater may save a significant amount of potable water (and its costs) for the homeowner or business installing a system, even though the payback period may exceed the useful life of the system. No cases of any disease have been documented to be caused by exposure to graywater—although systematic research on this public health issue is virtually non-existent. While this does not prove that there has never been such a case, the fact is that graywater is wastewater with microbial concentrations far in excess of levels established in drinking, bathing, and irrigation water standards for recycled water.

Graywater reuse is prevalent mainly in the semi-arid regions in the West and the South, but is not common at all in the Northern tier states. On the other hand, municipal water reuse is far more prevalent nationally, as it is driven by environmental regulations in addition to water supply scarcities. Thus, the impacts of increased graywater reuse vary regionally.

The quantitative impact of increased graywater reuse on the water reuse industry is expected to be modest, even under the most aggressive growth assumptions. Much of the growth in graywater reuse is expected to take place in areas where municipal water recycling will likely not be practiced—unsewered urban areas and rural and remote areas.

Water quality impacts from extensive use of graywater in a community are not expected to be adverse. In fact, bath and laundry water diverted from the wastewater stream, may marginally help reduce total dissolved solids, especially sodium, in the wastewater—and the reclaimed water derived from it. Organic load is only slightly higher in the remaining

SCOPE OF WHITE PAPER

This white paper is sponsored jointly by:

- WateReuse Association,
- Water Environment Federation, and
- American Water Works Association.

The White Paper is intended to help the Board of Directors of WateReuse Association adopt policies vis-à-vis graywater that are logical, fair, and consistent with the mission of the Association. The following objectives are the guiding principle for preparation of the document:

- 1) Characterize the most important issues in graywater and identify the policy implications of each;
- 2) Assess the potential impacts of rising trends in graywater use on the water recycling industry; and
- 3) Develop a regulatory and policy framework that will allow the industry to take appropriate actions to protect the integrity of the recycled water product and brand.

wastewater after diversion of graywater than before, with little or no impact on the carrying capacity of the sewers and in the ability of the biological processes in the treatment plant. However, the impact of reduced flow, when combined by the impact of other water conservation efforts in the community, may cause flow volume and velocity in the small-diameter extremity sewers to decline so much that the rate of deposition would exceed re-suspension.

Four policy options are proposed for discussion of the widest possible spectrum of choices and for ultimate decision on the part of the WateReuse Board of Directors:

- (1) Do nothing.
- (2) Distinguish graywater from recycled water and educate the public about the important differences.
- (3) Accept treated graywater reuse where the treatment and operational system meets applicable water reuse standards, ordinances, and regulations for the intended use.
- (4) Include reuse of all types of graywater as "water reuse" and gradually integrate them into the water reuse industry.

Fear of an adverse public health backlash from a future public health incident (e.g., an epidemic of cholera) related to graywater reuse have become intensified with the 2009 adoption by IAPMO (writers of the Uniform Plumbing Code (UPC), the International Plumbing Code (IPC), and other building and mechanical codes) to designate purple as the color for identification of pipes carrying all types of non-potable water—including graywater. Ideally, the color purple would remain strictly for use in identification of reclaimed/recycled water pipes and appurtenances. Since pipes carrying graywater are essentially within the private properties of the users themselves, it would be best if they remain black plastic irrigation piping as they are now—with adequate signage and markings to identify the non-potable nature of the water within. It would be highly desirable if a code provision were established that sets black as the standard for graywater conveyance. Pipe in black, green, and brown is readily available in many diameters, and in rolls, up to 1000 foot in length.

There may be an opportunity at this unique moment for the water reuse industry to take advantage of the relatively positive view of most members of the public about graywater and associate that goodwill with all water reuse.

It is recommended that research support be provided for increasing the state of scientific knowledge about graywater, risk assessment and risk comparisons under a variety of graywater reuse conditions, and relative public attitudes on graywater reuse and reclaimed/recycled water.

PART I INTRODUCTION

DEFINITIONS

Graywater

Graywater is untreated wastewater, excluding toilet and—in most cases—dishwasher and kitchen sink wastewaters. Wastewater from the toilet and bidet is “black water.” Exclusion of toilet waste does not necessarily prevent fecal matter and other human waste from entering the graywater system. Examples of routes for such contamination include shower and bath water and washing machine discharge after cleaning soiled underwear and/or diapers. California’s latest graywater standards define graywater thus:

..., "graywater" means untreated wastewater that has not been contaminated by any toilet discharge, has not been affected by infectious, contaminated, or unhealthy bodily wastes, and does not present a threat from contamination by unhealthful processing, manufacturing, or operating wastes. "Graywater" includes but is not limited to wastewater from bathtubs, showers, bathroom washbasins, clothes washing machines, and laundry tubs, but does not include wastewater from kitchen sinks or dishwashers¹.

This definition assumes that the homeowner would take extraordinary care in source control of contaminants and ensure a pathogen-free graywater, an assumption that would be questionable in a certain percentage of cases.

For the purposes of this white paper, “graywater” refers only to residential and commercial graywater, as defined in this section.

Rainwater Harvesting and Other Alternative Sources of Water

Rainwater harvesting involves systems that collect rainwater from rooftop catchments and other surfaces. The harvested rainwater comprises another alternative source of water. Water collected from these systems is generally not treated and includes contaminants collected on the catchment surfaces during dry intervals. The contaminants can include wind-blown dust, bird and rodent droppings, leaves and twigs from nearby vegetation, and other materials. Some of the more elaborate rainwater harvesting systems include a bypass that routes the initial runoff from each rainfall event to the storm sewer allowing subsequent (less-contaminated) runoff water to enter the storage reservoirs.

Harvested rainwater in catchment barrels and other storage devices is also considered graywater by many people—as is condensate from refrigeration equipment, collected stormwater, and other non-potable water sources that have not been contaminated with human waste. Nonetheless, for the purposes of this paper, they are considered as wastewater. Based on general knowledge in the field, it is estimated that these alternative sources are a minor component, compared to residential and commercial graywater, as defined above.

¹ Nonpotable water reuse systems, California Plumbing Code, Title 24, Part 5, Chapter 16A, Part I, August 4, 2009

Therefore, the main emphasis in this paper is on residential and commercial graywater, although much of the conclusions and recommendations are equally applicable to all alternative sources of non-potable water.

Treated Graywater Systems

Graywater from non-toilet, non-kitchen sources at a high-rise building, a sports stadium, or an apartment house is sometimes collected separately and treated in an on-site wastewater treatment plant. Blackwater is collected in a separate sewer and sent to the central treatment plant. Effluent from the on-site treatment system is then utilized as non-potable recycled water for uses similar to recycled water. The rationale for such systems is that (a) graywater sources within the building provide enough water for the non-potable water demand in the building and its vicinity, and (b) the lower solids loading, BOD loading, and microbial content of graywater make treatment less costly and less energy intensive. Such systems are common in Japan, especially in cities where developers of new buildings containing over 3,000 m² or over 5,000 m² (depending on local regulations) of usable space are required to provide on-site treatment and reuse—mainly for toilet flushing. These graywater systems utilize highly sophisticated treatment systems, including membrane biological reactors (MBR) and are closely monitored.

Treated graywater systems are not in common use in the United States at the present time; however, the advent of LEED certification and other sustainability incentives are expected to increase their utilization in the future. Treated graywater, meeting standards and regulations for water reuse, is essentially reclaimed water and is not the subject of this paper. However, lesser levels of treatment, especially those operated and maintained by homeowners, are common and do not necessarily provide adequate safeguards to those exposed to the water.

Water Reuse Industry

As used in this document, the phrase “water reuse industry” refers to public agencies (counties, cities, water districts, wastewater agencies, joint power agencies, etc.) involved in production, distribution or provision of recycled water to end users for beneficial reuse, replacing potable water. WateReuse Association is the principal national organization that represents the interests of the water reuse industry and supports research that enhances the safety and public understanding of water recycling.

Graywater Industry

In this paper, “graywater industry” refers to private-sector manufacturers, purveyors, and providers of graywater systems and subsystems as well as individuals engaged in promotion of graywater reuse and dissemination of information in its support. Surprisingly, the number of purveyors of graywater systems is rather small and most of them are outside the United States. The list of graywater system purveyors presented in Appendix A may not be exhaustive, but probably represents most of the suppliers active in the market at this time (October 2009).

RECYCLED WATER INDUSTRY CONCERNS ABOUT GRAYWATER

The recycled water industry in the United States has established an unblemished safety record in regulated use of highly-treated municipal wastewater for non-potable purposes. Nearly all recycled (or reclaimed) water used in urban settings is tertiary treated wastewater that has

been disinfected to virtually eliminate pathogens. Recycled water systems employ multiple barriers, site controls and other redundant measures, and are regulated by public health and environmental protection agencies.

Undisinfected secondary treated recycled water is also allowed to be used in some states for specific and restricted applications where human exposure is minimal, with additional site control requirements. A tabulation of California-allowed uses of recycled water—with four different levels of treatment—is presented in Appendix B.

There have not been any documented cases of human health problems due to water reuse under standards, criteria, and regulations. The water reuse industry is unwavering in its intent to maintain this record with diligent operation of water recycling systems and has worked hard to educate the public about its safety record. It is, therefore, not surprising that the industry is constantly on guard to prevent a reversal of its increasingly positive public image. WRA/AWWA/WEF comments to IAPMO have indicated that the primary issue is public health protection from cross connections and potential exposure to water of lower quality. This would apply to contamination of potable water or contamination of high quality reclaimed water by cross-connection with (or backflow of) graywater.

The recycled water industry takes immense pride in contributing significantly to our scarce water resources. Therefore, anything that might diminish the source of this water supply would be of great concern to the industry.

The concerns of the recycled water industry about graywater have been expressed with statements similar to the following²:

- Public health concerns related to the potential for cross-connection with either a potable or reclaimed water system;
- Fear of any health problems potentially caused by the poor microbial quality of graywater becoming associated with high-quality recycled water in the public's mind;
- Reduction of flow of raw material, as a result of diversion of graywater, into WWTPs for reliable production of recycled water;
- Public, media, and elected persons' confusion between graywater and recycled water and their respective qualities;
- Reduction in the carrying capacity of sewers for solids as a result of reduced flow into the sewer; and
- Increase in salinity of recycled water as a result of diversion of the lower-salinity bath, shower, and lavatory wastewaters from the sewer.

² These statements are neither exhaustive, nor necessarily wholly accurate, nor are they representative of water reuse industry's opinion as a whole. However, they do represent the opinions expressed by some prominent members of the industry at conferences and other public forums.

SOURCES AND CHARACTERISTICS OF GRAYWATER

State of Knowledge

Much of the information about graywater is currently available to the public on websites of graywater advocates and suppliers of equipment for graywater capture, storage, and application. There are a few scientific studies (e.g., Rose *et al.* 1991, Siegrist 1977, Casanova *et al.* 2001) and unpublished reports on pilot projects conducted for graywater reuse (e.g., City of Los Angeles 1992, California Department of Water Resources, 1996). The Water Environment Research Foundation (WERF) and the Soap and Detergent Association (SDA) have been cooperating in an intensive program of research into long-term graywater reuse, its characteristics and its effects on human health and the environment. A report of the first phase of this collaborative effort, primarily a literature search, has been published (Roesner *et al.* 2006).

Currently, a second phase of the WERF/SDA project is underway, performing controlled field research and characterization of existing sites with known long-term graywater reuse. This research project will consist of an analysis of pathogens in soil samples that have been collected from four homes in three states (California, Colorado and Texas), all of which have been using graywater to irrigate their landscapes for more than five years. Most of those systems reuse graywater generated from laundry machines; some also incorporate the graywater generated from baths, showers and bathroom sinks. Only one kitchen sink system is included in the study, and it is at the home of a vegetarian; if meat is prepared in the kitchen, the resulting graywater is typically contaminated with microorganisms and is a more high-risk wastewater. Information from this study, expected to be published in Spring 2011, is anticipated to shed additional light on a topic that is sometimes mired in controversy and misinformation.

Sources of Graywater

Figure 1 is reproduced from the above-mentioned WERF/SDA study, showing the typical urban distribution of indoor water usage in the United States.

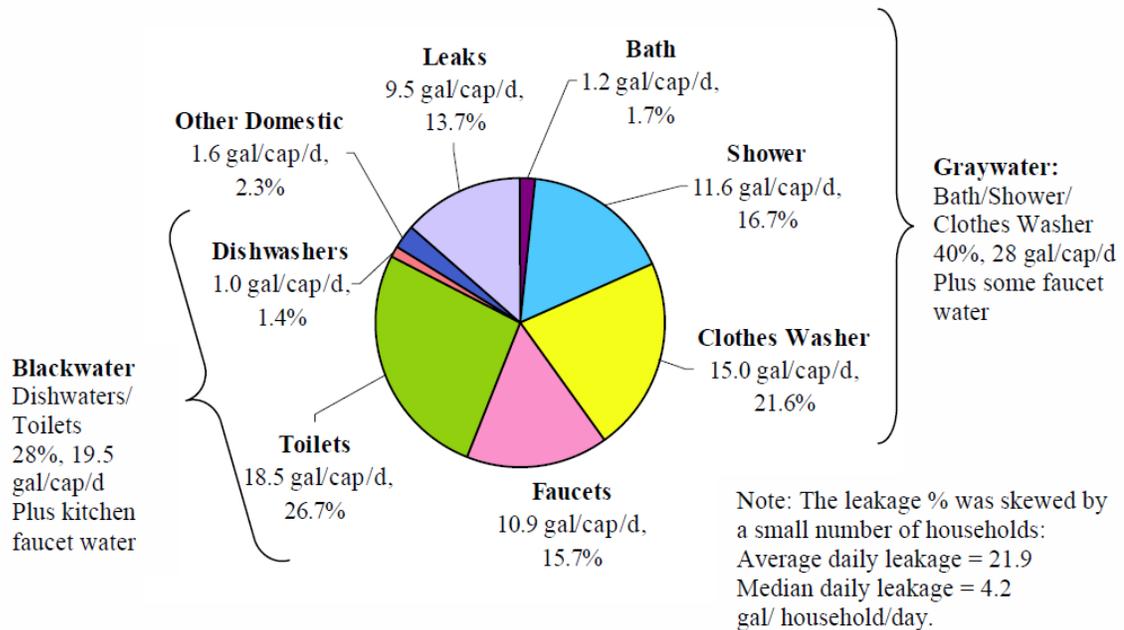


Figure 1 Average Indoor Residential Water Usage for 12 North American Cities
[Adapted from Residential End Uses of Water, by permission. Copyright ©1999, American Water Works Association and AWWA Research Foundation (AwwaRF).]

According to the AWWARF Survey of Residential End Uses of Water in 1999, graywater sources in an average household comprise more than half of the water used indoors, distributed as shown in Table 1—assuming an average of 2.6 persons per household. Most graywater reuse systems do not tap all of the sources of graywater shown in Table 1. Appendix C provides a reproduction of that survey's state-by-state daily graywater use volumes.

Table 1 Maximum Graywater Generation Rates in Typical US Households

Source	Percent of Indoor Use	Graywater Generation Rate		
		Gal/capita/day	Gal/household/day, 1999	Gal/household/day, 2030
Clothes Washers	21.6%	15.0	40	22.5
Showers	16.7%	11.6	30	25.0
Baths	1.7%	1.2	3	3.0
Faucets	15.7%	10.9	28	25.0
Total Graywater	50.6%	38.7	100	75.5

SOURCE: First three columns are based on data in Figure 1.

According to the 1999 Soap and Detergent Association survey, the average graywater system in the US only uses 6.3 gpd³. This is far lower than the potential maxima calculated in Table 1 to provide the upper range of potential future graywater reuse.

³ Calculated from the source statement: “The volume of graywater reused averages 188 gallons per month per household reusing graywater.”

Since 1999, many households have been retrofitted with modern water conserving fixtures and homeowners have adopted gradually increasing water saving ethic and habits. Therefore, the graywater generation volumes quoted above are on the high side of the scale and are not representative of current or future conditions. The projections of maximum graywater generation rates for the year 2030, shown in the last column in Table 1, are based on assumed pervasive adoption of more efficient water using fixtures and water saving devices.

When all graywater sources are tapped at a household, it can supply roughly half of the landscape irrigation needs of an average detached residential unit—with great variations based on household occupancy, local climate, lot size and type and extent of landscaping and its demand for irrigation water. Irrigation efficiency is another important factor. Drip irrigation systems are the most efficient and may be able to stretch the available graywater supply to meet most of the landscape watering needs of a typical household. Potable water must be supplemented in almost all situations for the remaining demand not met with graywater. This is one of the most compelling arguments for concern about cross connection and backflow potential, discussed further in Part II of this paper.

Microbial Quality of Graywater

Fecal coliform counts in graywater have been reported variously, ranging from thousands to millions of CFU/100 mL (City of Los Angeles 1992, Soap and Detergent Association, 2006, etc.) Table 2 shows the results of microbiological tests reported by several investigators.

Table 2 Microbial Properties of Graywater, MPN/100 mL or CFU/100 mL

Microbial Content	Siegrist 1977 Laundry	Novotny 1990	Rose <i>et al.</i> 1991	City Los Angeles 1992	Christova-Boal <i>et al.</i> 1996 bath	Casanove <i>et al.</i> 2001	Ottoson <i>et al.</i> 2003
Total Coliform	10 ²	10 ⁷ - 10 ⁸	2.5 x 10 ⁷	10 ⁴ - 10 ⁵	2.3 x 10 ³ - 3.3 x 10 ⁵	1.9 x 10 ⁸	1.3 x 10 ⁸
Fecal Coliform	10 ²	10 ⁶ - 10 ⁷	2.0 x 10 ⁴ – 7.9 x 10 ⁶	10 ¹ - 10 ⁵	2.0 x 10 ¹ – 3.3 x 10 ³	1.1 x 10 ⁷	--
Fecal Enterococci				ND – 1.6 x 10 ⁴			2.5 x 10 ⁴

SOURCES: Author names in column headings refer to list of references, at the end of the paper.

While these counts are mostly lower than those in raw wastewater, they are much higher than the levels allowed in various State regulations governing use of reclaimed or recycled water (e.g., California Water Recycling Criteria require total coliform levels <2.2 MPN/100 mL for most urban uses) corresponding to a virtually pathogen-free source of water. Because of its microbial content, states that do regulate and allow use of graywater for landscape irrigation generally require application of the water below the soil surface to minimize human exposure to the graywater. A comparative tabulation of water quality from several sources is presented below based on level of total coliform bacteria (in MPN/100 mL):

Drinking Water	<1
Disinfected Tertiary Recycled Water	<2.2
Disinfected Secondary Reclaimed Water	<23
Undisinfected Reclaimed Water	20 to 2000
Graywater	100 to 100 million
Raw Wastewater	millions to billions

The high number of indicator bacteria in graywater is cause for most public health officials to oppose reuse of untreated graywater without permits, restrictions and other regulatory controls.

VOLUME OF GRAYWATER INTERCEPTED

Volume of Graywater at the Use Site

As indicated above, graywater can comprise a significant portion of the water use at an individual use site—a home, an apartment, or a commercial enterprise—accounting for as much as 50 % of the indoor potable water use and meeting about half of the demand for outdoor irrigation use, during the irrigation season. For the user, this means a potentially big seasonal savings in water costs at the potable water meter. In most cases, it also means a concomitant savings in wastewater service costs to the consumer. Thus, the financial incentive for the homeowner to use graywater is significant, especially during drought periods when water rationing, prohibition of irrigation, and increasing-block (water conservation) pricing policies and fines for excessive use are in effect.

Volume of Graywater Diverted In the Community

While the individual user of graywater may potentially gain significantly from the decision to install a graywater system, the overall cumulative impact of graywater reuse on a given sewershed would be much smaller, percentage-wise. The following factors tend to modulate the overall use of graywater in the community:

- Many residential plumbing systems are already encased in concrete—where the housing unit is built on a slab—and the graywater component of wastewater cannot be readily separated from the blackwater component. Some (certainly not many) new housing units are now being built with stub-outs to enable separation of graywater based on the occupant's choice. Proposals to mandate such stub-outs have been vigorously opposed by the developer/builder industry for fear of litigation in case of a public health incident. The City of Tucson, AZ, is the only jurisdiction that has successfully mandated graywater stub-outs in new residential construction permitted after June 1, 2010.
- Where residential plumbing is accessible—in cases where the house is built on top of a basement or on piers—the possibility for easier separation of graywater sources exists, but this is not always a simple task or inexpensive. Thus, in many cases, it takes a devoted graywater enthusiast to perform the necessary plumbing changes—complete with acquisition of the necessary permits and hiring experienced plumbers to do so.
- Simpler graywater systems, involving the discharge of washing machine wastewaters or other readily accessible graywater components, are generally more prevalent than full-fledged systems capturing the maximum potential of the resource. Thus, the amount of water diverted by a graywater system can vary from under 40 to 100 gpd per household. A community-wide average value for graywater diversion per household may be significantly lower than the lower end of the range, because of the complexities, costs, and regulatory compliance necessary when capturing nearly all the graywater sources in the household.

There are no peer-reviewed survey research results available regarding actual volumes of graywater diverted and used. This is in part due to the fact that most of the existing graywater systems are “bootlegged,” without the benefit of formal permits and recorded construction drawings. It has been estimated that only about two percent of the graywater systems are legally installed. For the purposes of this paper, the graywater reuse information available in the gray literature has been assembled to calculate an estimate of the possible range of graywater volumes in the future.

Considering the factors enumerated above, the total number of households diverting graywater for onsite use is estimated to range from 660,000 to 1.77 million in California⁴ and 8 million in the United States⁵. Assuming an average of 75.5 gpd per household, the maximum total daily diversion of graywater in California would amount to 128 mgd in California and 604 mgd in the United States. Comparing these figures with current municipal wastewater capacity yields a round figure of 4 % for California. This is not a significant diversion from the wastewater that would otherwise end up at central treatment plants. In fact, wastewater flows from most wastewater collection systems is measured with a precision larger than plus/minus four percent.

Furthermore, not all of this diversion is subtracted from the volume of wastewater available for municipal reclamation, recycling and reuse. A large proportion of graywater systems are deployed in rural areas and in residences that are not connected to a central sewerage system and/or are not served with a piped water system. Thus, the diversion of graywater from their on-site treatment/disposal system would have no effect on a central water reclamation system. Figure 2 displays the envelope of diversion of graywater from the total raw wastewater resource, under a range of assumptions regarding the factors enumerated above. Basic assumptions, sources of data and the Excel sheet used in constructing Figure 2 are presented in Appendix D

⁴ The upper end of the range is obtained by multiplying 13.9 % of the households reusing graywater by the population of California and dividing by 2.6 persons per household. The 13.9 % figure is quoted from a 1999 graywater survey conducted for and reported by the Soap and Detergent Association. The lower CA estimate is derived from assuming that 5 percent of households have graywater, as opposed to 13.9 percent.

⁵ The higher CA estimate and the US estimate are according to Art Ludwig, Oasis Design, quoted in San Francisco Chronicle, September 18, 2009 and in the website <http://oasisdesign.net>.

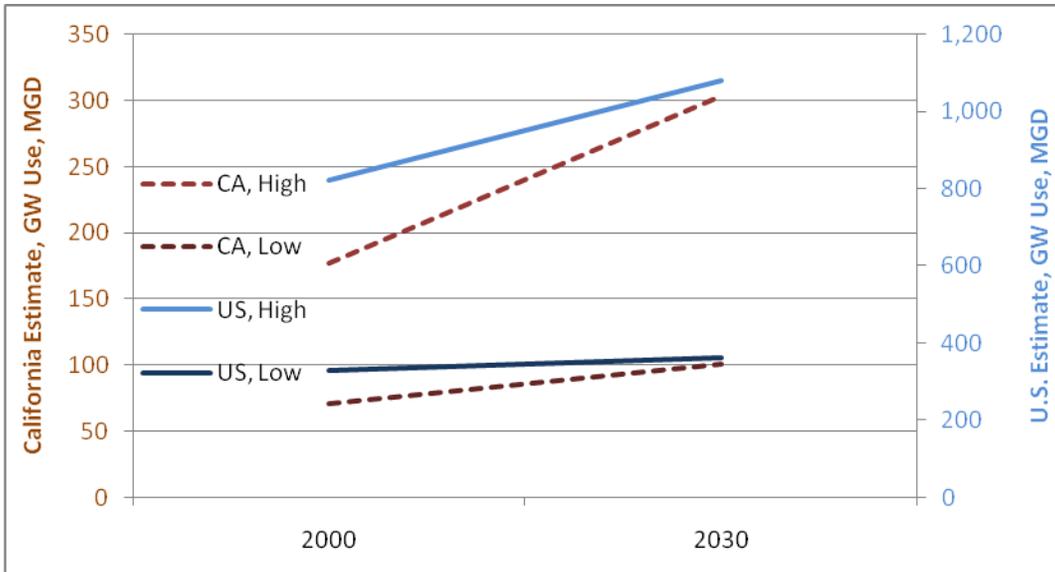


Figure 2 Estimated Growth in Graywater Reuse in California, and In the United States, under Two Scenarios: (a) Low- and (b) High-Rate of Increase in Penetration of Graywater Reuse Systems.

Water Rights Implications

Diversion of graywater from the wastewater stream may, in some states, violate water rights of the community enterprise that manages water and wastewater for the general benefit of the community. To date, there has not been a case in which a graywater user’s diversion has been challenged legally. As graywater reuse becomes more widespread, it may interfere enough with the operation of sewers and water reclamation facilities to engender legal or legislative action. Capture and use of harvested rainwater by homeowners was recently challenged in Colorado, but the Colorado legislature has favored allowing at least a limited collection and use of rainwater by residents (see sidebar).

“...some state officials, such as Rep. Marsha Looper, have pushed legislation to legalize at least some rain collection. Two such bills are now working their way through the state legislature: One would allow rainwater collection only in rural areas, while the other would green-light urban pilot programs. The new rules will test the effects of increased collection, Werner says—Colorado doesn’t want to let its millions of city-dwellers trap rainfall until they better understand the effects on the water system.”

--Popular Mechanics, April 22, 2009

According to the website of the Colorado General Assembly, the Governor of Colorado Signed HB09-1129 (Looper) into law on 06/02/2009.

“The Colorado Division of Water Resources regulates well water permits to prevent well pumping from injuring other water users. Graywater use may not be a permissible use of water under a well permit, due to return flow requirements that are part of the well permit’s approval. This must be clarified prior to installing a graywater system. In some cases, the conditions of approval under which a permit was issued would not prohibit the capture and use of graywater. In other cases, the permit conditions would not allow it. Specifically, if the

permit was issued for ordinary household purposes inside a single-family dwelling, with no outside uses, the capture and use of graywater for any use outside the dwelling (including lawn and garden irrigation (Figure 3)) would not be allowed⁶.”

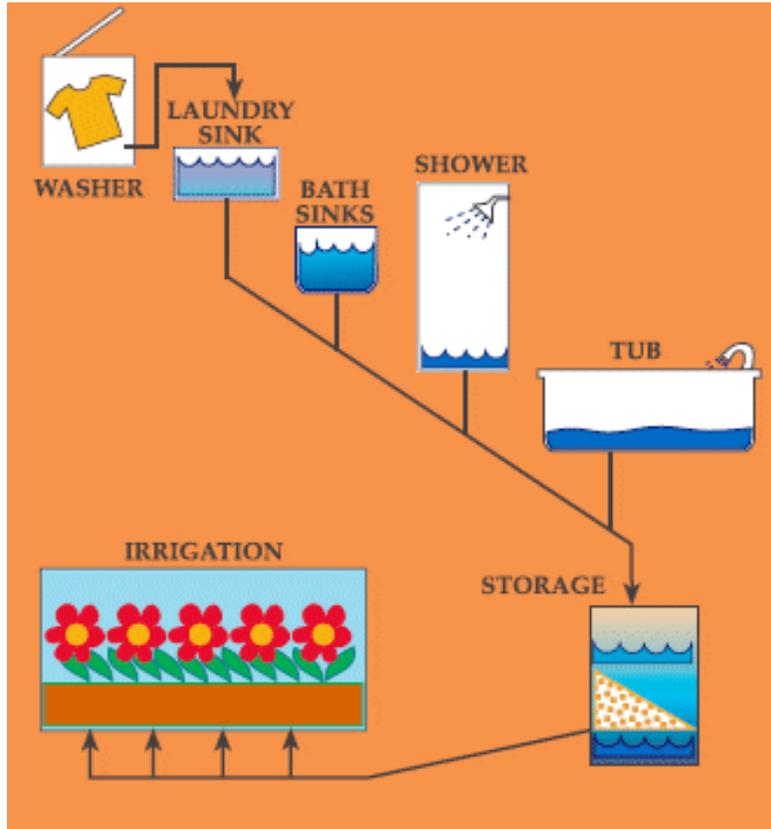


Figure 3. Sources of Graywater for Subsurface Irrigation of Landscape.
Source: <http://www.ci.tucson.az.us/water/greywater.htm>

⁶ <http://www.ext.colostate.edu/PUBS/natres/06702.html>

PART II GRAYWATER BACKGROUND

MOTIVATION FOR GRAYWATER REUSE

The motivation driving graywater reuse begins with the mindset of individual homeowners; their unwillingness to tolerate water rationing, their perceived lack of control over ever-increasing water rates, and their sense of personal investment in (and responsible for) the environment. These drivers are strong and can motivate action toward water and energy conservation, recycling, organic gardening, and other environmentally conscientious activities. Many households will never actually make an objective lifecycle cost analysis for these actions, relying instead on a strong belief in the rightness of their actions and expecting payback mainly through helping “save the planet”. Availability of simple plumbing equipment at the local hardware stores—especially during a drought and water rationing period, when graywater paraphernalia are prominently displayed—is another motivation to put graywater to use instead of tap water for irrigation.

HISTORICAL EVOLUTION OF GRAYWATER REUSE

In rural areas throughout the world, reuse of water that has already been used for washing, cleaning, and bathing has always been a common practice. With the advent of piped water systems and wastewater collection networks, this practice diminished in importance, especially as communities grew denser and became increasingly urbanized in the 20th Century. Population explosion, especially in the arid and semi-arid regions of the world has exerted a tremendous stress on available water resources. People have responded to water rationing, elevated water costs, and calls for water conservation with ingenious methods beyond those “best management practices” advanced by their water purveyors. Graywater reuse is indeed a re-discovery of a very ancient practice—one that went out of style because it was deemed unsanitary and potentially dangerous to the public health. Each episode of drought in the past 50 years has brought about a surge of new advocates and users of graywater with varying levels of sophistication.

Users of the simplest of graywater systems carry the warm-up water from the sink or bath to throw on their landscape plants. Others concoct plumbing systems that capture washing machine effluents. Still more elaborate systems build a second drainage system in their residence to capture nearly all graywater sources and lead them to storage tanks, treatment systems and application to the irrigated landscape areas on the property.

PERMITTED VS. UNREGULATED GRAYWATER SYSTEMS

It is common belief in the field that most of the existing graywater systems are operating without the benefit of a permit. Of the many systems in use in California, only about 200 are estimated to be operating with a permit, the ratio of permitted systems being about 0.01 % of total.

THE GRAYWATER INDUSTRY AND PRACTICES IN THE UNITED STATES

A few of the members of the graywater industry are well-trained professionals, but most are non-technical enthusiasts, interested in the water savings and environmental benefits of graywater reuse. Some are eager to promote its use without regard to economic, public health or actual environmental impacts and benefits of such use. In the following paragraphs, the graywater practices in states with the largest number of such systems are described.

Arizona

Arizona receives an average annual rainfall of 12 inches, the lowest in the Union. However, the Central Arizona Project imports more water from the Colorado River into the urban and agricultural centers of the state than there is current demand for water. Between the natural scarcity of water and the imported abundance, there is room for conservation and wise management of this vital resource. Over the last several decades, the state of Arizona has been the most permissive—in fact, encouraging—in its attitude toward graywater reuse by homeowners and commercial entities.

According to a 1999 survey of single-family homes in Southern Arizona, 13 % of the households reuse graywater.⁷ This survey was completed 10 years ago and the results may no longer be accurate. Given changes in regulations, and the current tax credit incentives to plumb for graywater in Arizona, one can presume that the percentage is similar or somewhat higher now. The survey concluded that households most likely to utilize graywater were older homes, lower value homes, homes with lower income levels, manufactured housing, and those on septic tanks. These factors appear consistent with assumptions about what motivates some people to reuse graywater, including:

- environmental sensitivity;
- water conservation ethic;
- desire to reduce one's water bill; and
- desire to reduce one's sewer bill or to prolong the life of an on-site disposal system.

The College of Agriculture and Life Sciences of the University of Arizona established two public demonstration projects in 1985 to promote use of graywater, among other water-conserving strategies and systems. The following is quoted from the University's website⁸:

“Casa del Agua and Desert House are experiments set up to test and evaluate various water saving devices and strategies including graywater reuse and rainwater harvesting in residential facilities. Casa del Agua is a Tucson residence that was retrofitted with water-conserving fixtures and reuse technologies and landscaped with drought tolerant plants. As an occupied domestic residence, Casa del Agua provides a setting to research and test

⁷ Water Conservation Alliance of Southern Arizona (WATER CASA), 1999, “Residential Graywater Reuse: The Good, The Bad, The Healthy”

⁸ <http://ag.arizona.edu/azwater/arroyo/071rain.html>

domestic water use and conservation strategies. Casa del Agua also is an educational project, open to the public during scheduled hours.

“Constructed in the Desert Botanical Garden in Phoenix, Desert House is a water- and energy-efficient exhibit consisting of a house and an adjoining information center. Dedicated on May 8, Desert House also will be home to a family. By living with and using the installed water-and-energy efficient technologies, the family will test and demonstrate their effectiveness. Desert House includes graywater reuse and rainwater harvesting systems. A public information center is part of the facility.

“Both projects emphasize that saving water is not just good public policy, but also wise household management. In other words, water saved is both a personal and public good. The projects are meant to demonstrate that graywater reuse and rainwater harvesting systems enable a household to participate more actively in the community effort of conserving water.”

Guidelines for reuse of graywater⁹ were published in English and Spanish by WATER CASA to encourage graywater reuse and to promote safe and legal application of graywater in the Arizona households.

The City of Tucson provides a tax credit to graywater users as an incentive to encourage this practice¹⁰.

California

The California graywater usage and public interest in it rise and fall with occurrences of drought, water rationing, and restrictions on lawn irrigation. During the recurring drought episodes (in the 1970s, in the early 1990s, and again during the current drought, now possibly in its fourth consecutive year) much newsprint has been devoted to graywater. California was the first state to establish graywater reuse regulations (in 1994). California’s first graywater standards were in Appendix G of the California Administrative Code. Recently, these standards were replaced with a significantly more permissive Chapter 16A, intended to encourage increased graywater reuse in the state.

During the drought of the 1990s, the City of Los Angeles established a temporary “Office of Water Reclamation,” charged with integrating, fostering, and facilitating the water reuse efforts of its various departments. The Los Angeles City Council instructed the Office of Water Reclamation to conduct a year-long pilot study of graywater reuse in eight residences in various parts of the City. The report of that study¹¹ concluded that the soil in areas irrigated with graywater tended to have higher concentrations of indicator bacteria, but that “the soil is already so heavily contaminated with animal fecal matter that the additional contribution of graywater may be irrelevant.” It also concluded that while the homeowner may be able to save a significant volume of water by using graywater, the community-wide

⁹ Little, Val L., 1999, “*Graywater Guidelines*” WATER CASA, The Water Conservation Alliance of Southern Arizona.

¹⁰ <http://www.ci.tucson.az.us/water/greywater.htm>

¹¹ City of Los Angeles Office of Water Reclamation, “Graywater Pilot Project”, November 1992. The pilot study included eight residential home sites volunteered by prominent members of the City’s administration for the one-year duration of the study.

water savings are not expected to be significant. The City of Los Angeles has recently adopted an ordinance that encourages reuse of residential graywater systems within the City.

Illegal (bootlegged) graywater installations range from simple hose connections to the laundry waste line to more complicated systems capturing most of the graywater sources within the household.

Some communities in California encourage use of graywater and others are considering the possibility of offering financial support to members of the public as an incentive for graywater systems.¹² Graywater reuse is considered a “potential best management practice” (PBMP) by the California Urban Water Conservation Council, and can be counted toward meeting the water conservation goals established in a Memorandum of Understanding among the water agencies and environmental interests in the state.

Florida

Graywater reuse in Florida has not taken off to the same extent as in the West. A few high-end homes are installing approved graywater systems for indoor and/or outdoor use in order to become LEED certified. There could be other homes that have installed these systems, but officials are not aware of them. Officials receive more inquiries on using rain water harvesting systems (cisterns to store rainwater) for outdoor and other non-potable uses, than they do graywater inquiries. And, there are a large number of homes in Sarasota County that have installed cisterns for supplementing irrigation water use. The reason graywater systems are not widespread in Florida may be because they are costly compared to other water conservation projects such as low flow toilets, rain sensor installations, etc., which are very popular and successful.¹³ Also, Florida enjoys frequent rainfall and reliable reclaimed water service to over 250,000 homes.

Most municipal sewer system entities in Florida do not allow their customers to install graywater systems. Some officials predict that the use of these systems could result in insufficient sewer flows to carry the waste to the sewer plant. There is also a potential for a reduction of the availability of reclaimed water due to less effluent flowing to the plant for treatment. Based on this line of reasoning, graywater systems may be more feasible for Hardee, DeSoto, and portions of Hernando, Polk, and Sumter counties due to the fact that those counties do not have reclaimed water systems versus Pinellas, Pasco and Hillsborough counties with existing regional reclaimed water systems.¹⁴

Other States

Graywater reuse in other states is not widely practiced, except in isolated rural areas where it may serve as another wastewater disposal function.

¹² Personal communication with Ms. Victoria Cross, City of Los Angeles Department of Water and Power.

¹³ Information about Florida graywater reuse was obtained in email correspondence with Ms. Melissa Musicaro, Staff Water Conservation Analyst, Resource Projects Department, Southwest Florida Water Management District

¹⁴ Musicaro, M., Potential for Drip Effluent Disposal Systems in the Southwest Florida Water Management District, Resource Conservation and Development Department, Southwest Florida Water Management District, Brooksville, Florida, September 2003

KEY LEGISLATIVE MODELS, REGULATIONS, STANDARDS, AND GUIDELINES

Only around 30 of the 50 States have regulations allowing, prohibiting, or regulating graywater reuse in one form or another. The diversity of such regulation is illustrated in Appendix E where the regulatory structure of some of the states, as of 2004, are summarized—including updated information about California. A far more detailed summary of state-by-state graywater regulations is available in the undated Texas literature search report¹⁵, from which the Appendix E tables were adapted.

Several states, including North Carolina, only allow graywater reuse if it is first treated to standards identical to those required for water reclamation from the complete wastewater stream (black and gray water combined). In the following sections, the regulations or code standards of a few of the States—those with the most pro-active (and generally more permissive) standards—are described.

Arizona

To make the process easier for homeowners who want to reuse graywater at their homes, the Arizona Department of Environmental Quality (ADEQ) developed graywater rules with stakeholder input.¹⁶ Many of these rules are based on the results of a graywater study conducted in the Tucson area.¹⁷ The basic requirements to reuse graywater are simple: Residents must adhere to the guidelines for a Reclaimed Water Type 1 General Permit. A Type 1 General Permit requires no formal notification to the department, no review or design approval, and no public notice, reporting, or renewal. Although one need not apply to receive a formal permit to reuse graywater, the homeowner must abide by the 13 best management practices (BMPs) listed below, which were developed to protect public health and water quality:

1. First and foremost, avoid human contact with graywater, or soil irrigated with graywater.
2. You may use graywater for household gardening, composting, and lawn and landscape irrigation, but use it in a way that it does not run off your own property.
3. Do not surface irrigate any plants that produce food, except for citrus and nut trees.
4. Use only flood or drip irrigation to water lawns and landscaping. Spraying graywater is prohibited.
5. When determining the location for your graywater irrigation, remember that it cannot be in a wash or drainage way.
6. Graywater may only be used in locations where groundwater is at least five feet below the surface.
7. Label pipes carrying graywater under pressure to eliminate confusion between graywater and drinking water pipes.

¹⁵ San Antonio Water System, Texas A&M University's Cooperative Extension, University of Texas, San Antonio, Center for Water Research, Texas Onsite Wastewater Treatment Research Council, "Graywater Literature Search", c. 2004

¹⁶ The following section is adapted from a public information brochure published by the Arizona Department of Environmental Quality

¹⁷ www.watercasa.org/research/residential/resindex.htm

8. Cover, seal and secure storage tanks to restrict access by small rodents and to control disease carrying insects such as mosquitoes.
9. Graywater cannot contain hazardous chemicals such as antifreeze, mothballs and solvents. Do not include wash water from greasy or oily rags in your graywater.
10. Graywater from washing diapers or other infectious garments must be discharged to a residential sewer or other wastewater facility, unless it can be disinfected prior to its use.
11. Surface accumulation of graywater must be kept to a minimum.
12. Should a backup occur, graywater must be disposed into your normal wastewater drain system. To avoid such a backup, consider using a filtration system to reduce plugging and extend the system's lifetime.
13. If you have a septic or other on-site wastewater disposal system, your graywater use does not change that system's design requirements for capacity and reserve areas.

The Mayor and Council of the City of Tucson, Arizona adopted an ordinance in September 2008 requiring that :

“All new single family and duplex residential dwelling units shall include either a separate multiple pipe outlet or a diverter valve, and outside “stub-out” installation on clothes washing machine hook-ups, to allow separate discharge of graywater for direct irrigation.

“All new single family residential dwelling units shall include a building drain or drains for lavatories, showers, and bathtubs, segregated from drains for all other plumbing fixtures, and connected a minimum three (3) feet from the limits of the foundation, to allow for future installation of a distributed graywater system.

“All gray water systems shall be designed and operated according to the provisions of the applicable permit authorized by ADEQ under the Arizona Administrative Code, Title 18, Chapter 9.”

California

Appendix G of the California Plumbing Code was the regulatory standard for graywater reuse in California from 1994 until recent revisions and adoption of Chapter 16a of the Code. Just before the long drought of the 1990s abated, the California Department of Water Resources published a detailed “Graywater Guide”¹⁸ with step-by-step instructions on how to install a graywater system and distribute the water for landscape irrigation while meeting the graywater standards in effect at that time. This publication received wide distribution and is now out-of-print.

Through the cycles of drought, a few suppliers of graywater systems, designs, and information have survived and apparently thrived. Chief among them are Oasis Design¹⁹, Graywater Action²⁰ (formerly called Graywater Guerillas), and ReWater Systems, Inc²¹.

¹⁸ California Department of Water Resources, “Using Graywater in Your Landscape: Graywater Guide”, December 1994.

¹⁹ <http://www.oasisdesign.net>

²⁰ <http://greywateraction.org/>

²¹ <http://rewater.com/>

These purveyors/activists and a larger number of individuals have been lobbying the State legislature for a more friendly code provision for graywater systems. In February 2008, State Senator Alan Lowenthal introduced SB-1258 (Building standards: graywater), which would instruct the Department of Housing and Community Development to adopt revised standards for construction of systems for indoor and outdoor use of graywater. The legislators telegraphed their intent for a more permissive code, with the following paragraph:

14877.1. (a) The department, in consultation with the State Department of Public Health and the Center for Irrigation Technology at California State University, Fresno, shall adopt standards for the installation of graywater systems. In adopting these standards, the department shall consider, among other resources, "Appendix J," as adopted on September 29, 1992, by the International Association of Plumbing and Mechanical Officials, the graywater standard proposed for the latest edition of the Uniform Plumbing Code of the International Association of Plumbing and Mechanical Officials, the City of Los Angeles Graywater Pilot Project Final Report issued in November 1992, and the advice of the Center for Irrigation Technology at California State University, Fresno, on the installation depth for subsurface drip irrigation systems.²²

The bill was passed by the legislature and approved by the Governor July 22, 2008. The California Department of Housing and Community Development (HCD) then initiated a lengthy consultation process with the stakeholders to develop a revised section (Chapter 16-A of the California Plumbing Code) for graywater. Based on the testimony presented at public forums, and after several cycles of revisions and extensive comments, the final code language was adopted as an emergency measure by the Building Standards Commission and became effective on August 4, 2009.

"These new graywater standards will be a big step toward reducing California's water consumption by providing cost-effective guidelines that will be beneficial to every home throughout the state," said Director Lynn L. Jacobs. "HCD and its staff recognize the importance of continually improving the state building codes and standards to help improve our sustainability."

The new code provides that simple graywater systems using only one fixture—such as a washing machine—need not obtain a permit as long as they comply with 12 specified conditions in the code:

1. If required, notification has been provided to the Enforcing Agency regarding the proposed location and installation of a graywater irrigation or disposal system.

Note: A city, county, or city and county or other local government may, after a public hearing and enactment of an ordinance or resolution, further restrict or prohibit the use of graywater systems. For additional information, see Health and Safety Code Section 18941.7.

2. The design shall allow the user to direct the flow to the irrigation or disposal field or the building sewer. The direction control of the graywater shall be clearly labeled and readily accessible to the user.

²² Copied verbatim from the final version of the bill at <http://www.legislature.ca.gov/cgi-bin/port-postquery>

3. The installation, change, alteration or repair of the system does not include a potable water connection or a pump and does not affect other building, plumbing, electrical or mechanical components including structural features, egress, fire-life safety, sanitation, potable water supply piping or accessibility.
4. The graywater shall be contained on the site where it is generated.
5. Graywater shall be directed to and contained within an irrigation or disposal field.
6. Ponding or runoff is prohibited and shall be considered a nuisance.
7. Graywater may be released above the ground surface provided at least two (2) inches (51 mm) of mulch, rock, or soil, or a solid shield covers the release point. Other methods which provide equivalent separation are also acceptable.
8. Graywater systems shall be designed to minimize contact with humans and domestic pets.
9. Water used to wash diapers or similarly soiled or infectious garments shall not be used and shall be diverted to the building sewer.
10. Graywater shall not contain hazardous chemicals derived from activities such as cleaning car parts, washing greasy or oily rags, or disposing of waste solutions from home photo labs or similar hobbyist or home occupational activities.
11. Exemption from construction permit requirements of this code shall not be deemed to grant authorization for any graywater system to be installed in a manner that violates other provisions of this code or any other laws or ordinances of the Enforcing Agency.
12. An operation and maintenance manual shall be provided. Directions shall indicate the manual is to remain with the building throughout the life of the system and indicate that upon change of ownership or occupancy, the new owner or tenant shall be notified the structure contains a graywater system.

The old provision for burial of graywater lines more than nine inches below the soil surface was reduced to two inches, allowing for mulch or gravel for cover. The graywater industry is evidently delighted with this revised version, based on the comments posted on the Internet since adoption of the new code. However, local jurisdictions can impose additional restrictions and requirements—or, simply prohibit graywater systems. The City of San Francisco’s Building Inspection Commission proposed a local ordinance that included reversing the “no-permit” provisions in the CPC Chapter 16 and mandated inspections of installed graywater systems. Intense efforts by graywater advocates and purveyors resulted in a reversal by the Building Inspection Commission on October 21, 2009—with instructions to perform yet another pilot study of graywater reuse from the washing machines. The graywater industry feared that the San Francisco example, viewed generally as a sustainability pioneer in the state, would set an unfavorable precedent for other jurisdictions to follow.

Florida

Florida’s regulations for graywater are defined in Appendix C, Sections C101 to C103 of the *2007 Florida Building Code-Plumbing*. Sections C101.1 to C103.11 cover all requirements for graywater recycling systems in Florida. It appears that graywater reuse applies to both residential and commercial applications, although that is not specifically stated in the text.

Section 301.3 of this code requires “all plumbing fixtures that receive water or waste to discharge to the sanitary drainage system of the structure.” To allow for the utilization of graywater systems, Section 301.3 has been revised to allow exceptions such as water from bathtubs, showers, lavatories, clothes washers and laundry trays where such fixtures discharge to an approved graywater system for flushing of water closets and urinals or for subsurface landscape irrigation.

“Retention time for graywater used for flushing water closets and urinals is a maximum of 72 hours. The holding capacity of the reservoir shall be a minimum of twice the volume of water required to meet the daily flushing requirements of the fixtures supplied with graywater, but not less than 50 gallons (189 L). **The graywater is required to be dyed blue or green** with a food grade vegetable dye before such water is supplied to the fixtures.

“The distribution piping and reservoirs must be identified as containing non-potable water. Potable water is to be used as a source of makeup water for the graywater system, with the potable water supply protected against backflow. For subsurface landscape irrigation systems, reservoirs need to be sized to limit the retention time of graywater to a maximum of 24 hours. The reservoir must be identified as containing non-potable water. Makeup water is not required for subsurface landscape irrigation systems.

“For residential use, graywater discharge is based upon occupancy and the type of fixtures connected to the graywater system. Occupancy is determined by the actual number of occupants, but not less than two occupants for one bedroom and one occupant for each additional bedroom. Each occupant is allotted 25 gallons per day for showers, bathtubs and lavatories and 15 gallons per day for clothes washers or laundry trays. For commercial uses, the number of occupants is determined by the *Florida Building Code-Building*.”

Texas

The Texas Administrative Code has provisions for reuse of graywater for domestic purposes, Industrial, Commercial, or Institutional Purposes, and for Irrigation and for Other Agricultural Purposes. In the following sections, the rules for domestic uses of graywater are reproduced (with slight modification of formatting and organization).

An authorization is not required for the domestic use of less than 400 gallons of graywater each day if:

- (1) the graywater originates from a private residence;
- (2) the graywater system is designed so that 100% of the graywater can be diverted to an organized wastewater collection system during periods of non-use of the graywater system and the discharge from the graywater system must enter the organized wastewater system through two backwater valves or backwater preventers;
- (3) the graywater is stored in tanks and the tanks:
 - (A) are clearly labeled as nonpotable water;
 - (B) must restrict access, especially to children;
 - (C) eliminate habitat for mosquitoes and other vectors;
 - (D) are able to be cleaned; and

- (E) meet the structural requirements of §210.25(i) of this title;
- (4) the graywater system uses piping that meets the piping requirement of §210.25 of this title;
- (5) the graywater is applied at a rate that:
 - (A) will not result in ponding or pooling; or
 - (B) will not cause runoff across the property lines or onto any paved surface; and
- (6) the graywater is not disposed of using a spray distribution system.

Builders of private residences are encouraged to:

- (1) install plumbing in new housing to collect graywater from all allowable sources; and
- (2) design and install a subsurface graywater system around the foundation of new housing to minimize foundation movement or cracking.

A graywater system as described in subsection (a) of this section may only be used:

- (1) around the foundation of new housing to minimize foundation movement or cracking;
- (2) for gardening;
- (3) for composting; or
- (4) for landscaping at the private residence.

The graywater system must not create a nuisance or damage the quality of surface water or groundwater.

Homeowners who have been disposing wastewater from residential clothes-washing machines, otherwise known as laundry graywater, directly onto the ground before the effective date of this rule may continue disposing under the following conditions.

- (1) The disposal area must not create a public health nuisance.
- (2) Surface ponding must not occur in the disposal area.
- (3) The disposal area must support plant growth or be sodded with vegetative cover.
- (4) The disposal area must have limited access and use by residents and pets.
- (5) Laundry graywater that has been in contact with human or animal waste must not be disposed onto the ground surface.
- (6) Laundry graywater must not be disposed to an area where the soil is wet.
- (7) A lint trap must be affixed to the end of the discharge line.

Graywater systems that are altered, create a nuisance, or discharge graywater from any source other than clothes-washing machines are not authorized to discharge graywater under subsection (e) of this section.

North Carolina

According to the 2006 North Carolina Plumbing Code, treated household graywater may be permitted for use for specific purposes, if treated according to Code Standards. In Appendix C, Section C101.1, the code allows graywater to be used for flushing toilets that are located in the same building as the graywater recycling system if the graywater is properly treated, including filtration and disinfection. These recycling systems can also be used for irrigation purposes when approved by the authority having jurisdiction. Appendix C includes information regarding the installation, filtration, disinfection, drainage and identification of graywater recycling systems.

Other States

New Mexico is following Arizona's lead in implementing statewide regulations for graywater. The New Mexico Environmental Department (NMED) policy on graywater allows up to 250 gallons per day of graywater to be used without a permit. Nevada, Massachusetts, Oklahoma, Utah, and Colorado either have some graywater policies or are adding graywater laws, regulations, codes, and guidelines. In New York, Appendix 75-A.10 states that home systems shall be designed with a minimum capacity/use rate of 75 gallons per day/per bedroom. A state-by-state tabulation of graywater regulations is presented in Appendix E.

FUTURE TRENDS IN GRAYWATER SYSTEMS AND REUSE

Future water scarcity is almost universally expected to worsen in the arid and semi-arid regions of the world, simply because of population expansion and migration patterns. Global climate change is also expected to exacerbate this trend in most dry, populated, and especially poorer regions of the earth. Household reuse of graywater is seductive to people faced with the prospect of water rationing, increasing block rates for water, and periods of continuous drought. Even without encouraging or permissive legislation, the motivation to utilize household graywater becomes stronger as awareness of water shortage and looming scarcity increases. It is expected that these influences will push graywater reuse to its logical limits over the coming decades. Those limits are discussed and quantified in Part 1 of this paper. It is probable that graywater legislation will increasingly accentuate control of human exposure at individual reuse sites and, to a lesser extent, higher levels of treatment. Higher levels of treatment will be required for indoor uses, such as toilet flushing—where people are more likely to be exposed unknowingly to the water. Higher levels of treatment (water quality) and informative signage should be required in public access buildings where the public may unknowingly be exposed to untreated or inadequately treated graywater.

Satellite Water Recycling vs. Individual Graywater Systems

Tapping main sewer lines for production of recycled water is a common practice in some parts of Australia. In the United States, such systems are becoming more, because of their locally economical features and their ability to produce recycled water at the location where demand for non-potable water is dire. The relevance of satellite water recycling to graywater is that a communal satellite water reuse system can obviate the need for graywater capture and reuse without treatment. By the same token, widespread use of graywater in a community can preclude economical implementation of a satellite water recycling plant in that community.

LEED Certification Water Efficiency Points

One of the significant incentives for reuse of graywater in future residences and in commercial buildings is the point credit system used by green building certification organizations, such as LEED (The Leadership in Energy and Environmental Design Green Building Rating System²³, developed by the [U.S. Green Building Council](http://www.usgbc.org) (USGBC)). This system provides a suite of standards for environmentally sustainable construction. Since its inception in 1998, LEED has grown to encompass more than 14,000 projects in the United States and 30 countries covering 1.062 billion square feet (99 km²) of development area.

The goal of the Water Efficiency credit category is to encourage smarter use of water, inside and out. Water reduction is typically achieved through more efficient appliances, fixtures and fittings inside and water-wise landscaping outside. For example, a major residential high-rise in New York City was awarded gold LEED certification in 2004 for a variety of environmental and green features, including use of both graywater and rainwater for irrigation of rooftop and other landscaping²⁴ as well as recycled water for toilet flushing.

LEED is an internationally recognized green building certification system, providing third-party verification that a building or community was designed and built using strategies aimed at improving performance across all the metrics that matter most: energy savings, water efficiency, CO₂ emissions reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts.

Developed by the U.S. Green Building Council (USGBC), LEED provides building owners and operators a concise framework for identifying and implementing practical and measurable green building design, construction, operations and maintenance solutions.

LEED is flexible enough to apply to all building types – commercial as well as residential. It works throughout the building lifecycle – design and construction, operations and maintenance, tenant fit-out, and significant retrofit. LEED for Neighborhood Development extends the benefits of LEED beyond the building footprint into the neighborhood it serves.

²³ <http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1988>

²⁴ <http://www.thesolaire.com/index.html>

INFRASTRUCTURE

Plumbing Codes Pertaining to Graywater²⁵

Several organizations develop and publish plumbing codes and building codes. Each jurisdiction selects the code it would adopt and often modifies the adopted code to fit its own needs, laws in effect, and special circumstances. The Uniform Plumbing Code (UPC) is developed iteratively, over a 3-year cycle, by the International Association of Plumbing and Mechanical Officials (IAPMO) and used by most jurisdictions as their own basic regulation for indoor plumbing in buildings. The International Plumbing Code provides similar language for other jurisdictions that also requires purple colored pipe for non-potable waters.

Since the mid-1990s, the UPC has included graywater as a source of water for irrigation of landscape—albeit with conditions that mimicked closely onsite disposal fields. Over the past three years, the Plumbing Technical Committee—a group that is charged with the development of the code—reviewed and voted on proposed language that was included in the 2009 edition of the UPC²⁶. IAPMO and was published in the January 2009 edition of the UPC. Specifically, the Plumbing Technical Committee proposed that the 2009 edition of the UPC, at Sections 1610.2 and 1617.2, specify the use of a purple background with specific cautionary language on pipe intended to deliver onsite alternate water, including any water produced onsite that is not potable. This includes graywater, harvested rainwater, air conditioner condensate, stormwater, and untreated surface water and groundwater. To individuals involved in municipally treated reclaimed water systems, the immediate alarm was use of purple pipe to deliver non-potable water of uncertain quality. In most cases, the onsite alternative water sources, including graywater, would be of lower quality than tertiary-treated and disinfected reclaimed water. Recommendations for changes to be considered in the 2012 UPC must be submitted to IAPMO by Feb 1, 2010 to qualify for the review and public comment cycle.

The revisions to the 2006 UPC simply changed the pipe color from yellow with black uppercase text to purple pipe with black uppercase text. This change to the color purple raised concern among water utility professionals, and motivated a new proposal to change the designation of pipe color for graywater from purple to another color—possibly black, as is currently the case with irrigation piping commonly used for application of graywater to the landscape.

IAPMO members also active in the Society of Plumbing Engineers on the Plumbing Technical Committee did not want additional use designation for yellow pipe, as yellow is used to designate flammable gas piping. This was accepted as a valid public safety concern. Another primary driver for this action appears to be the movement to LEED-certified buildings and sustainability. Many elected officials are leading their staffs toward “green” design. Where there have been code conflicts, IAPMO has been asked to eliminate the barriers to use of alternate waters in the building environment. The choice of purple pipe was IAPMO’s solution for conveying those various non-potable water sources. The issue is that there is no one monitoring the re-circulating graywater quality, frequency of sampling, capability or certification of operators or maintenance of the systems.

²⁵ Most of the text in this section is adapted from Vandertulip, D., P.E., “Purple Pipe for All Waters?” in Conference Proceedings of WEFtec’09, 82nd Annual Water Environment Federation Technical Exhibition and Conference, Orlando, Florida, October 2009.

²⁶ The International Plumbing Code (IPC) follows a similar three-year cycle of code revisions.

Conflicts with State, Local Regulations

*Conflict with Return-Flow Credit*²⁷

A major conflict exists where any wastewater is reused consumptively²⁸ and not returned to the original source for credit. Such use deprives the community of its ability to extract the amount of water that was thus consumed—evaporated. A prime example is in Las Vegas Valley, Nevada. Wastewater in the valley is collected and treated by three cities and Clark County Water Reclamation District. A total of 190 million gallons per day of treated effluent is returned to Lake Mead via the Las Vegas Wash, and is counted as an approximate 190,000 acre-foot per year (AF) credit that is added to Southern Nevada’s 300,000 AF Colorado River allocation.

In Southern Nevada, water recycling that ends up in evaporation of the water—including graywater reuse—would not reduce water demands or increase water supply. This is because the current discharge of wastewater effluents to Las Vegas wash already recycles all water used non-consumptively (over 60 % of the water) in the valley. Since any graywater used for irrigation would have otherwise been sent to a wastewater treatment facility and recycled by way of Lake Mead, no water is saved with graywater diversion and reuse. The volume of graywater from laundry, bathing and bathroom sinks is about half of the total wastewater volume discharged from a typical residence. Using graywater on-site for irrigation could pose a significant reduction in the return flow credit. As a result, a policy of the Southern Nevada Water Authority and Clean Water Coalition governing boards, adopted in December 2008, declares:

“Prohibit the use of treated or untreated Graywater in the Las Vegas Valley, and prohibit its use outside of the valley where there is reasonable potential for return flow to the Colorado River system or other Water Recycling programs.”

Color Coding Pipes, Signs, Appurtenances

Transmission of graywater rarely occurs outside the immediate confines of the site where it was generated—nor is such transfer tolerated by any of the existing guidelines, rules and regulations. Nearly all graywater conveyance is within the household, from the collection drains to a storage (surge) tank, and thence to the landscaped area via irrigation pipes—normally black plastic pipes ending in spaghetti tubing feeding in-line or terminal emitters. Conveyance of graywater on a larger scale may occur in a commercial or multi-unit residential setting. Even in those instances, the reuse of graywater generally occurs within the confines of the same commercial or apartment housing unit without the need for external piping. Thus, there exist very little—if any—pipes carrying graywater in public rights-of-way over a significant distance.

Residences and other private and public areas receiving reclaimed/recycled water from a municipal source for landscape irrigation or other purposes would necessarily use purple piping inside their service areas strictly for conveying reclaimed/recycled water. A potential

²⁷ Most of the material in this section is taken almost directly from Rimer, Alan E, “*Graywater Is not Reclaimed Water*,” in Conference Proceedings of WEFtec’09, 82nd Annual Water Environment Federation Technical Exhibition and Conference, Orlando, Florida, October 2009.

²⁸ Consumptive use of water includes irrigation, use in cooling towers and other uses that culminate in loss of water to the atmosphere by evaporation and plant use. Non-consumptive use of water includes washing, cleaning, flushing, and any other uses that do not significantly reduce the volume of water before discharge to the sewer.

conflict would be envisioned if a site with such access to recycled water were to use graywater also, and piped it in purple-colored lines. The potential for cross-connection at such sites constitutes a direct potential threat to the public health.

Many State and local agencies have adopted the color purple for identification of pipes and fixtures used for conveyance of recycled/reclaimed water. The unblemished public health record of recycled water is associated with the color purple as a branding mechanism to the public eye. That brand may be tarnished and compromised if alternate sources of water (including graywater) with inferior microbial quality are also associated with this color. This conflict looms large especially because of the tremendous public investments in reclaimed/recycled water systems constructed in recent years throughout the United States. Those investments were based on the public's confidence in the safety of municipal water reuse. Should that confidence become shaken with a public health incidence—e.g., an epidemic of cholera due to a “purple-pipe” transmission—it would be very difficult to explain the difference between gray and recycled water. Already, many politicians and public members misuse “graywater” when they mean reclaimed/recycled water. Use of the color purple for graywater pipes would reinforce that misconception.

Florida is the one state where residential use of reclaimed water is very common. In fact, at this writing there are about 250,000 single-family residences with recycled water service for landscape irrigation (front and back yards) in Florida.²⁹ A family receiving recycled water at a relatively low cost has little or no motivation to resort to graywater reuse. Thus one might assume the possibility of having both types of water in the same residential unit would be a rarity. Nevertheless, the State of Florida has opted to forbid use of purple piping for any but reclaimed water conveyances. The State has formally opposed the 2009 UPC provision for designation of purple color for all alternative water sources.

Compatibility with Utilities' Practices and Standard Specifications

Designation of the color purple for pipes carrying all types of non-potable water would be incompatible with the practices and standard specifications adopted by many utilities that have invested in a water reuse infrastructure. While local jurisdictions are at liberty to modify parts of the UPC as they adopt new updates, the very existence of a code section that conflicts with existing general practice and standard specifications can cause confusion and potential mis-connections, cross-connections, and backflow.

Storage of Graywater

Storage of graywater is necessary because the timing of its production and utilization is usually not the same. Generally, a 50-gallon (or smaller) storage tank is sufficient for a residential graywater system. It is not advisable to store graywater for more than 24 hours, because of the potential for decay of organic matter, odors, and unsightliness. Large-scale storage of graywater is unknown and is unlikely to occur. Regulations for reuse of graywater require marking of such storage containers with large clear warning signs indicating that the water therein is non-potable, unsafe, and may be dangerous if someone is exposed to it.

²⁹ Based on data from Florida Department of Environmental Protection 2007 Reuse Inventory Report, Appendix F, Public Access Reuse Systems in <http://www.dep.state.fl.us/water/reuse/inventory.htm>

Distribution and Application Systems

Nearly all graywater is used on-site where it is generated. Usually, graywater is applied beneath the soil surface with drip irrigation emitters and non-clogging nozzles. Most regulations of graywater prohibit spray and other aerial applications of graywater to limit human exposure to the microbial content of graywater. Older systems were based on disposal criteria and were unconcerned with uniformity and efficiency of application to the root zone. Problems arise when runoff or seepage from one residence invades a neighbor's property, producing ponding, algae growth, and/or odors. Neighbor complaints about graywater reuse (and misuse) next door are received and reported by some utilities and public service individuals in charge of water conservation efforts.

Indoor Reuse of Graywater (Toilet Flushing)

Graywater used for toilet flushing indoors must be treated to standards similar to those of reclaimed water: filtration and disinfection of secondary effluent. By the time such treatment is provided, graywater is already of the same quality as tertiary (or Class A) reclaimed water and is indistinguishable from it. Conveying tertiary-treated graywater in purple pipes should not cause conflicts or confusion or pose a public health problem—as long as the treatment system and their operations are in compliance with regulations governing similar uses of recycled or reclaimed water.

Cross-Connection Control

Graywater reuse is most likely to be practiced where the site has no access to recycled water. Conversely, where recycled water is distributed to households (as in many Florida cities), the homeowner has no incentive to spend \$1000 or much more to install a graywater system. The odd situation may be where some neighbors opt to use the available recycled water and others elect to use their own graywater—for whatever reason. This situation is where the potential for cross-connection is the greatest. Another potential area of concern is on a golf course where purple pipe would be carrying as many as four different types of nonpotable water, producing a high cross-connection potential. There can also be cross connection between reclaimed water and any four of the alternate waters or cross connection between rainwater and graywater, etc.

Graywater is generally conveyed in low-pressure irrigation tubing under gravity or low-pressure pumping to the points of use. Under normal operating conditions, even an intentional cross-connection between the graywater lines and potable lines at a given site would result in discharge of potable water to the landscape. However, if a pressure-drop in the potable water system should occur, then a cross-connection can result in contamination of the community water system with graywater from the site. While this is a rare occurrence, precautions for its prevention must be taken. The 2009 UPC designation of purple piping is a genuine, well-intentioned attempt at minimizing the possibility of inadvertent cross-connection between potable water and graywater pipes

The same objective can be accomplished with another color (preferably black) and clear marking of the pipes (E.G., CAUTION: GRAYWATER—DO NOT DRINK) in English and Spanish, or another language that is common in the area.

Backflow Prevention

Backflow of graywater into the community water supply can occur if all three of the following conditions are simultaneously present:

- (a) graywater is ponded on the surface of the soil, or in a tub, bucket, etc;
- (b) the open end of a potable water hose is left submerged in the ponded water; and
- (c) a prolonged pressure drop in the potable water lines of the community is experienced.

Such an occurrence, though extremely rare, is a possibility and must be actively prevented by avoiding ponding and preventing use of potable water hoses in areas irrigated with graywater. Some jurisdictions require installation of backflow preventers on the potable water supply lines coming into sites using any alternate water supply. Color coding of the graywater lines will not have a positive impact in prevention of backflow.

Use of Hose Bibbs

As indicated above, use of hoses in areas irrigated with graywater can lead to backflow of graywater into the community water supply under some circumstances. To prevent this from happening, some jurisdictions require capping of exterior hose bibbs.

Stub-outs in New Buildings

When a new building is being constructed, the opportunity for separating graywater sources from toilet, bidet, and kitchen drains is at its best. Some developers use this opportunity to complete the new structure with a graywater-ready stub-out. The occupant can then decide whether or not to use the stub-out and install a graywater system at a later time. The City of Tucson, AZ actually requires such stub-outs in new residential construction. All new homes built in Tucson will be required to include plumbing for a graywater system.

The new rules require plumbing—also called stub outs—for graywater systems for all new homes that are issued permits after June 1, 2010. The regulations affect only new construction, not existing houses, unless the homeowner builds an addition with a new bedroom, bathroom and kitchen. A newly constructed guesthouse on an existing property would also be required to include graywater plumbing. It is expected that this feature will become more widely used and advertised in the future as a water-saving feature and as a “green-building” advantage to the prospective homebuyers.

ECONOMIC ASPECTS OF GRAYWATER

System Costs

Graywater system costs vary over a wide range. The most elementary systems, with do-it-yourself kits and equipment purchased from the hardware stores cost under \$1,000. The more sophisticated systems offered on the market by specialized providers of such systems cost in the range of \$2,500 to \$8,000³⁰.

“Under the old state codes, California property owners essentially had to install costly leach fields and apply for permits - driving the total for a graywater project as high as \$10,000.”

“The new regulations allow property owners to set up systems for as little as \$200.”

(Zito, 2009)

³⁰ <http://rewater.com/>

Potable Water Savings Potential

While at least one source has indicated that graywater reuse leads to increased water use,³¹ most other reports indicate a range of water (and money) savings to the homeowner using graywater. The City of Los Angeles Graywater Pilot Project final report (1992)³² calculated an average savings of 50 % of water use in a household if the amount of graywater generated closely meets the demand for water for landscape irrigation—especially where highly efficient subsurface drip irrigation is utilized. In most cases, there is either too little landscaping for the graywater generated or too little graywater generated for the demand. Thus, actual average water savings tend to be considerably lower than 50 %.

Wastewater Service Savings

Since graywater would have normally been sent to the sewer, the household using graywater for irrigation earns a double benefit from reduced charges for wastewater treatment. However, if the utility adjusts the wastewater factor for the residences using graywater, this savings may be diminished considerably.

Environmental Impacts and Sustainability (Greenness)

By their nature, graywater systems are small, individual, and not subject to the lengthy environmental review processes that the much larger municipal water reuse systems must undergo. Thus, the cumulative impacts of graywater systems are never considered at the planning stage of their implementation.

As actual water shortages, droughts, and awareness of water scarcity become increasingly popular topics in the media and public discourse, any measure to reduce demand for water is viewed favorably and given credit toward achieving sustainability goals. Graywater is no exception. In fact, graywater appears to be more favorably viewed by the public at large than the much more sophisticated water reuse projects proposed in some parts of the world (notably Southern California, Florida, and Australia in recent years). Most environmental activist groups support both graywater and recycled water projects.

Cost-Effectiveness for the Home/Business-Owner

Most homeowners installing graywater systems do so to preserve their landscaping in the face of water rationing, to avoid fines, and/or to be good stewards of the environment. Cost-effectiveness of graywater systems varies widely, depending on the sophistication of the system, cost of potable water saved, and cost of labor. According to Kreysig (1996),³³ graywater recycling, including a disinfection and “electrochemical treatment step” can result in significant cost savings for homes and industry. However, other studies appear to

³¹ This is based on a quote: “The rebates for alternative water sources...appear to be very effective. The exception appears to be graywater reuse systems that are associated with an increase in consumption of scheme water” attributed to Waterwise Rebate Scheme Review 2007, Data Analysis Australia Pty Ltd, April 2008. This was reported in the Southern Nevada Regional Water Recycling Study conducted jointly by Southern Nevada Water Authority, Clean Water Coalition, and Black & Veatch in a public outreach brochure. (Original reference was not found.)

³² City of Los Angeles Office of Water Reclamation, *Graywater Pilot Project* final report, , November 1992.

³³ Kreysig, D. “Greywater Recycling: Treatment Techniques and Cost Savings”. Water Conservation and Recycling, v19.3 (1996): 18-19

conclude the opposite. The City of Los Angeles Office of Water Reclamation pilot study metered the graywater diversion, and concluded that the amount of water saved in six (of the eight) residential sites over a 12-month period ranged from a mere 2.2 to 11 % of the total water use at the sites. While all pilot test systems and installation labor were donated by the purveyors for the pilot project, the actual cost of the systems ranged from \$400 to \$5,000. Even the simplest system could not have been cost-effective based only on the value of water saved—although actual calculations were not reported in the pilot project’s final report. In another similar pilot study conducted by the California Department of Water Resources³⁴ at three disparate sites, the costs of the systems installed far exceeded the value of the 20-year water savings. A simplistic benefit/cost analysis indicates that the monetary benefits alone did not justify the costs of these three systems:

Graywater Test Location	Cost of Equipment	Value of Water Saved Over 20 Years	Benefit/Cost Ratio	Payback Period, Years
Santa Barbara	\$1,131	\$893	0.79	25
Danville and Castro Valley	\$5,400	\$895	0.17	120

Avoided Costs to the Community

Advocates of graywater claim that the community benefits from reduced demand on stressed water supplies plus a reduction of wastewater flow into treatment plants. No quantitative data have been provided to illustrate the extent of such avoided costs to the communities in which graywater is used to a significant extent. On the contrary, water utilities and wastewater agencies generally have an unenthusiastic attitude toward graywater reuse in their service areas. They cite public health concerns, loss of revenue, hindrance of sewer lines’ ability to carry solids, and the potential for cross-connection with potable water lines as negative aspects of increased graywater reuse by households (Rimer, 2009).

Energy Use and Carbon Footprint

Since graywater systems bypass the collection system, central treatment, and redistribution of reclaimed water, they simply avoid the amount of energy needed for operating those facilities. Thus the carbon footprint of graywater systems can be argued to be much smaller than that of a centralized water recycling program of the same size. However, it should be recognized that a community with a built collection, treatment and reticulation system for recycled water has already invested a tremendous amount of resources (including energy and its CO₂ emissions) in those infrastructure elements. For a community that is not sewered, perhaps graywater systems can be counted on to reduce the capacity requirement of future sewerage facilities, if it can be shown that the graywater systems will in fact be maintained and sustained over the long term. At this point, this is a speculative possibility, current design criteria would not permit reduction of wastewater flow based on graywater reuse, and there are no case studies to confirm its applicability. However, there are anecdotal cases of some graywater systems that have been in use for as long as 30 years.

³⁴ Bennett, R. et al., 2002. *Monitoring Graywater Use: Three Case Studies in California*, reprint available at <http://oasisdesign.net/greywater/SBebmudGWstudy.htm>

Comparison with Municipal Water Recycling

Water reuse project proposals are subject to intense public scrutiny in the planning stages. In some states the proposal must undergo a lengthy environmental review process—including an assessment of its cumulative, long-term impacts—before it is approved to move forward. By contrast, a graywater installation can be operational without any public involvement and with no assessment of its cumulative impacts. In a recent paper, Rimer (2009) compared graywater with municipal recycled water from several viewpoints and concluded:

“Graywater may be considered a resource for single family homes, and even commercial establishments, but there are significant public health and environmental risks associated with its use. Overcoming those risks through adequate treatment that is supervised by a professional may be the only way to assure its safe use. On the contrary, the use of reclaimed (recycled) water has none of these issues. It is a highly treated wastewater that must meet stringent state and local standards and is conveyed in purple pipe for delivery to residential, commercial, industrial and agricultural users.

“Differentiating graywater and reclaimed water is a task that public and private utilities must work in concert with public health agencies to assure that the public is aware of the significant water quality differences. With the pending changes in the plumbing code, this may be a more difficult task than the utilities realize.”

Cost-Effectiveness for Society

Since the homeowner (or the business manager) usually bears the full costs of constructing and operating the entire graywater infrastructure and its operation and maintenance, it can be argued that it relieves the community from that much of the burden of wastewater management. With minimal or no cost, the society reaps a finite benefit—avoided costs of conveyance, treatment, and redistribution. No matter how small this avoided cost may be, the benefit/cost ratio for society is (at least mathematically) very high. Graywater reuse may be viewed as a privatized version of water reuse—no direct costs to the public except those costs that may be externalized; principally public health and environmental impacts and related costs for patient care and environmental mitigation. This is a potential area for future research.

PUBLIC HEALTH CONSIDERATIONS

Graywater is untreated wastewater. Even though graywater systems exclude toilet and kitchen wastes, numerous studies have shown significant concentrations of fecal coliform and other indicators in graywater samples collected at actual use sites and in the soils receiving graywater (Rose *et al.* 1991, City of Los Angeles 1992, Siegrist 1977, Casanova *et al.* 2001). These concentrations (see Table 2) are far greater than the maximum levels allowed under current federal, state, and international standards for water uses involving human contact (drinking, bathing, parks irrigation, etc.)

Thus, arguments against allowing widespread and uncontrolled use of graywater have been based on the microbial quality of graywater and the need for either (a) adequate treatment, and/or (b) prevention of exposure to graywater. Since treatment to the disinfected tertiary level at each graywater reuse site is both expensive and difficult to maintain, monitor, and

control, most regulations governing use of graywater rely on minimizing human exposure by specifying systems that preclude such exposure. (The more expensive graywater systems on the market do include filtration and disinfection prior to distribution of graywater.)

Proponents of graywater systems cite the fact that there have been no *documented* cases of public health impacts associated with graywater reuse over the last several decades. The reason for this lack of documentation may be twofold:

1. Adverse health outcome from exposure to graywater may be difficult to isolate and causally associate with graywater, because of the complicated multi-exposure environments in which we live. Domestic animals, for example, can be a source of exposure to microbial contamination from outside the home, or improperly cooked poultry or meat may be other possible sources of pathogen transfer.
2. Compliance with effective graywater regulations, minimizing exposure, may have been effective enough to prevent the majority of cases that would have otherwise arisen.

The investigators in charge of the long-term study of graywater reuse, currently ongoing under the joint sponsorship of Water Environment Research Foundation and Soap and Detergent Association, are examining public health and other outcomes from sites that have been in graywater reuse for as long as 30 years. The results of that study are expected to be published in the Spring of 2011. It is anticipated that a conclusive statement about this issue will not be forthcoming from this project either, principally because of the impossibility of proving the negative.

The microbial character of graywater notwithstanding, graywater advocates vigorously claim that there has never been any public health impact from use of graywater, as “documented” in the data reproduced in Table 3.

Table 3 Incidence of Recorded Communicable Diseases in California, with Potential and Recorded Linkage to Graywater, Extrapolated to the Last Sixty Years

Disease, Potentially Linked to Graywater	Cases in 2007	Est. 60-Year Cumulative Cases	Cases Linked to Graywater
Cholera	7	288	0
Cryptosporidiosis	11,170	502,650	0
E. coli, Shiga toxin-producing (STEC)	4,847	218,115	0
Giardiasis	19,417	873,765	0
Hepatitis A	2,979	134,055	0
Legionellosis	2,716	122,220	0
Salmonellosis	47,995	2,159,775	0
Shigellosis	19,758	889,110	0
Vibriosis (non-cholera Vibrio species infections)	447	20,115	0
Totals	123,713	4,920,093	0

SOURCE: Oasis Design © Feb 24, 2009

<<http://oasisdesign.net/greywater/law/california/index.htm>>, reproduced/adapted with permission from Art Ludwig.

Risk Assessment

Risk is a fact of life. Nothing is risk-free and “zero risk” is only a mathematical concept impossible to achieve practically in any human endeavor. Reusing untreated graywater in a residential landscape may involve a low (acceptable) or a high (intolerable) microbial risk, depending on exposure scenarios and other factors. Unfortunately, adequate and accessible risk information about graywater is not available at this time—with a few exceptions, cited further below. Individuals intent on using graywater to reduce their water costs or to maintain their landscape in a drought condition do not have access to credible risk information about reuse of graywater. They are told by advocates and purveyors that graywater is safe—without a scientifically based foundation. Graywater advocates cite lack of documented diseases associated with graywater reuse. While this is not proof of lack of such risk, and while the null hypothesis is impossible to prove, the risks associated with exposure to raw wastewater are well-documented in historical episodes of epidemics of transmissible diseases.

Another important risk consideration is whether it is voluntary or involuntary. Humans are much more willing to take voluntary risks than to be subjected to risk by others—a neighbor, the landlord, a business, a manufacturer, or the government (Sandman, 1995). Thus, an untreated graywater reuse system in one’s own backyard is far more acceptable (and perceived to be far more controllable and safer) than a graywater system imposed by the apartment management or a highly treated water reuse system proposed by the local water agency. A neighbor’s graywater runoff into the landscape is often cause for legal action and heated arguments. Thus, risk assessment and evaluation can have multiple perspectives and variations, complicated with acceptability issues and familiar v exotic risk. Consider the outrage from terrorists’ and murderers’ killings compared with the public’s blasé attitude toward 40,000 highway deaths each year.

Homeowners generally are not proficient at maintaining sophisticated mechanical systems at home—septic tanks, water softeners, point-of-use water treatment devices, or graywater systems—especially those involving chemical and mechanical treatment processes. This increases the risk of exposure to pathogens as a result of having a graywater system. In spite of these inherent obstacles, graywater users take on the responsibility for their own family’s use of graywater and unwittingly accept the risks involved. A larger problem arises when an apartment building or a commercial enterprise utilizes graywater and potentially exposes others—who have no choice in taking on the additional risk—to graywater constituents.

Dixon *et al.* (1999) assessed the potential threat to health associated with the microbial contamination of graywater. They interpreted the results of their risk analysis into a conceptual tabulation, as reproduced, with minor modifications, in Table 4.

Table 4 Conceptual Analysis of Range of Risk from Graywater Reuse

Risk Factors	Lower Risk	Intermediate Risk	Higher Risk
Population	Small (Single-Family)		Large (Multi-Occupancy)
Exposure	No body contact (subsurface irrigation)	Some contact (toilet flushing)	Ingestion (drinking)
Dose-Response	<1 virus/sample, <1 bacteria/sample		>1 virus/sample, >10 ⁶ bacteria/sample
Delay before Reuse	Immediate reuse	Reuse within hours	Reuse within days

SOURCE: Adapted from Dixon *et al.*, 1999.

A screening-level quantitative microbial risk assessment (QMRA) was undertaken by Ottoson (2002) for *rotavirus*, *Salmonella typhimurium*, *Campylobacter jejuni*, *Giardia lamblia* and *Cryptosporidium parvum* in Swedish graywater. Different exposure scenarios were validated for the three applied risk estimate approaches in the QMRA.

- (1) Accidental ingestion of 1mL treated graywater,
- (2) Yearly risk from direct exposure after irrigation with graywater, assuming 1mL intake/day and 26 days/year.
- (3) Yearly risk from drinking groundwater recharged from the pond.

Median risk of infection based on six exposure scenarios and three methods ranged from $10^{-0.2}$ for rotavirus to 10^{-11} for salmonella. In this study, graywater was subjected to some treatment, but according to the authors treatment efficiency was very low. Applicability of this study to untreated graywater is therefore somewhat dubious. The authors make the following recommendation regarding guidelines for graywater reuse:

“In conclusion we suggest that guidelines for graywater recirculation and reuse should not be based on thermotolerant coliforms as a hygienic parameter, because of the large input of non-faecal coliforms and/or growth of coliforms. The overestimation of the faecal load, and thus risk, that the indicator bacteria give is however to some degree compensated for by the higher susceptibility to treatment and environmental die-off. The risk model based on faecal enterococci densities correlated well to the risk from viruses, which is supposed to be the most prominent in a system without disinfection due to their high excretion figures, environmental persistence and low infectious doses. If guidelines should be based on bacterial densities, faecal enterococci are preferred.”

Diaper *et al.* (2001) conducted a preliminary Hazard and Operability (HAZOP) study and identified the main hazards, both health related and economic, associated with installing a recycling system in a domestic environment. The health related consequences of system failure were associated with the presence of increased concentrations of micro-organisms at the point of use, due to failure of the disinfection system and/or the pump. The risk model was used to assess the increase in the probability of infection for a particular genus of micro-organism, *Salmonella* spp, during disinfection failure. The increase in the number of cases of infection above a base rate rose from 0.001% during normal operation, to 4% for a recycling system with no disinfection (i.e., untreated graywater). The simulation model was used to examine the possible effects of pump failure. The model indicated that the anaerobic COD release rate in the system storage tank increases over time and dissolved oxygen decreases during this failure mode. These conditions are likely to result in odor problems.

Risk Management

Regulations, guidelines and standards established by various states for reuse of graywater are essentially risk management tools mandated by the governing body on the populace. Their effectiveness is in part measured by the level of compliance in actual practice. The very low estimate of compliance in California (0.01 %) with the more stringent regulations of the

earlier standards was in part responsible for relaxation of those standards in recent months. The graywater industry anticipates a higher rate of compliance with the new Chapter 16A standards, and wider employment of professional installers for establishing future graywater systems

Many “how-to” publications have been prepared and distributed by various water utilities to inform and advise the public about safe use of graywater. All of these public information pieces attempt to manage the risks inherent in use of untreated wastewater. Judging by the recent public clamor for a more relaxed graywater regulation in California, these risk management efforts may have been successful enough so that the general public now holds a positive image of graywater reuse. It remains to be seen whether or not the recently approved more relaxed regulations will result in adverse public health outcomes, resulting in a public backlash and cause a return to the more stringent regulations of the past.

Dixon *et al.* propose a risk management framework for the United Kingdom by concluding:

- A framework for guidelines for the reuse of graywater has been proposed, which forms a summary of a desk-top risk-assessment study sourced from current and long-standing published material on risk, graywater re-use and other modes of water reuse.
- The framework takes into account the paramount importance of protecting public health whilst recognizing the realistic levels of risk posed by various modes of graywater re-use within the context of everyday human activity.
- Areas where there is either an expectation for responsibility or a personal acceptance of responsibility with regard to public or personal health, have been identified.

PART III WATER RECYCLING INDUSTRY- GRAYWATER INTEGRATION FRAMEWORK

IMPACTS OF INDIVIDUAL GRAYWATER REUSE ON MUNICIPAL WATER RECYCLING

Planning for Future Volumes of Recycled Water

If graywater reuse becomes more widespread, it may affect the flow of wastewater into the water reclamation facilities of the community. This is a factor that has not been taken into consideration in past planning for community sewerage or water recycling programs. A simple analysis for each community can yield a graphic depiction of the impact of graywater reuse—similar to that shown in Figure 1 for the United States and for California as a whole. In most densely populated urban centers, the envelope of impact is expected to be marginal and negligible. In suburban and rural areas, particularly in the arid and semi-arid regions, the impact can be expected to be significant, especially if climate change results in reduced water supplies in those areas.

Possible Benefits of Graywater for the Water Recycling industry

A possible benefit of graywater for the water reuse industry may be in the realm of public perception, attitude, and acceptance. Currently, the lay public everywhere seems to hold a positive image of graywater. It is seen as a resource emanating from and belonging to themselves. Also, those who make the decision to reuse the graywater do so completely voluntarily, and without incentives or fear of penalties. Most graywater users do so against the law and install systems without a permit, some at considerable cost. They accept the inherent risks voluntarily, whether or not they are aware of the magnitude of those risks.

The fact that most of the public view graywater positively, combined with the fact that most people do not clearly distinguish graywater from recycled water provides an opportunity for the water reuse industry to design public outreach programs that embrace safe use of graywater while also touting the superior quality of recycled water. Over time, the public perception of recycled water may undergo an evolution based on education and subtle persuasion—somewhat similar to the way the advertising industry re-images a product by association with the positive aspects of an unrelated aspect of everyday life.

Quantitative Impacts of Graywater

Flow Reduction to WWTPs

The exact amount of reduction of flow to water reclamation plants must be calculated individually and separately for each community, given a survey of penetration rate of graywater systems, types of system in use, and the seasonal nature of their use. The variability of impact from one community to another would be great and generalizations would be subject to error.

Carrying Capacity of Sewers for Suspended Solids

Total suspended solids (TSS) content of domestic wastewater typically ranges in the 200 mg/L range. If half the water and none of the solids were diverted to graywater reuse, that concentration would double to around 400 mg/L. This is still extremely dilute and not necessarily conducive to deposition by itself. However, the effect of reduction of flow (Q) in the sewer line by half on velocity of flow (V) is more important in determining whether or not material will deposit in the sewer at lower velocities. If the sewer is already flowing nearly full, a reduction of 50 % in flow will not affect the velocity of flow enough to allow suspended materials to settle. If, on the other hand, the sewer is flowing at a small fraction of its capacity, then a reduction of 50 % of the flow can have a large impact on flow velocity, potentially resulting in deposition of suspended solids in the sewer.

In areas with shallow slopes, and in older sewer lines that may have undergone partial settling and uneven slopes, the carriage of solids in wastewater can be problematic, resulting in settling and clogging over time. These problems would be somewhat exacerbated if a significant portion of the wastewater (as much as 50 percent in some systems) were diverted for graywater irrigation. However, few graywater systems tap the entire flow of graywater. Usually, only the most accessible components (laundry water, some lavatories, the bathwater) are tapped. Also, the sewer lines most vulnerable to such potential clogging would be the smallest laterals serving detached individual dwellings and associated subdivision mains deprived of adequate flow to maintain cleansing velocity. Larger community sewers would only experience a relatively small reduction in overall flow because of the relatively low percentage of dwellings using graywater systems in the community.

Water Quality Impacts

Graywater diversion can affect the quality of wastewater remaining for reclamation by removing the fraction of the wastewater containing the highest concentration of dissolved solids and sodium—from laundry soaps and personal care products from the lavatories and baths. This may have a beneficial impact on the mineral quality of water reclaimed from the remaining wastewater stream. The higher concentration of total suspended solids is likely to result in marginally more efficient treatment at the central treatment plant, especially in the biological processes.

POLICY AND PLANNING APPROACH FOR WATER RECYCLING INDUSTRY

WaterReuse Association has a leadership role nationally, and its policies reflect and lead the way various regions of the country deal with water reuse—in all its variations. It is anticipated that whatever graywater policies are adopted by the Association will become strong guidance for members in different parts of the country. It is also possible, that some regional sections of the Association may elect to go forward with policies that may differ from the national organization in significant ways. This is a healthy situation and can lead, in the long-term, to the ultimate selection of the most appropriate policies.

The water reuse industry has a wide range of policy options vis-à-vis graywater reuse. These options comprise a continuum, one extreme of which involves standing solidly apart from graywater (and other untreated wastewaters) and the other extreme involves full integration with the graywater industry. Four distinct options, at the far ends of the continuum and in between, are:

- (1) Do nothing.
- (2) Distinguish graywater from recycled water and educate the public about the differences.
- (3) Accept treated graywater reuse where the treatment system meets applicable water reuse standards, regulations, or local ordinances for the intended use.
- (4) Include reuse of all types of graywater as "water reuse" and gradually integrate them into the water reuse industry.

Option 1. Do Nothing

Conduct business as usual, paying scant attention to developments in the graywater arena. Many graywater papers have been delivered at WateReuse symposia in the past, without much discussion of their relevance (or lack thereof) to water reuse, *per se*. The “do-nothing” option is a middle-ground position, similar to *status quo*.

Option 2. Distinguish and Distance Recycled Water from Graywater

This option would involve a robust campaign to educate the public and its elected representatives about the differences between recycled water and graywater, alerting decision-makers about the risks inherent in exposure to untreated wastewater, and distancing the industry from the graywater proponents and purveyors. The WateReuse Association would advise its members to inform themselves about the risks of reuse of untreated graywater and other wastewaters within their jurisdictions. The Foundation would support research into documentation of the relative safety of recycled water in contrast to graywater. An assertive approach would be taken to prevent public confusion between graywater and recycled water.

Option 3. Accept Properly Treated Graywater Reuse

The Association would make a special exception where the graywater treatment system meets applicable water reuse standards, regulations, or local ordinances for the intended use of properly treated graywater, under professional maintenance and supervision.

Option 4. Include Graywater Reuse

This option would involve a gradual integration of the graywater industry into the water reuse industry. As a subset of the water reuse industry, graywater reuse would become another one of the several “flavors” of used water already purveyed by members of the industry. The proper place and appropriate uses and precautions necessary for graywater reuse would be clearly defined, just as those of other classes of reclaimed/recycled water are already defined. Any areas of conflict would be resolved with technical and regulatory fixes as the unified industry evolves in the future.

Under this option, WateReuse Association would encourage membership from the graywater industry members, along with proportionate representation. WateReuse Foundation would support research into proper and safe use of graywater, under appropriate conditions. A collaborative effort would be initiated with state public health and environmental protection agencies to ensure appropriate standards for both reclaimed water and graywater.

Comparison of Options

The pros and cons of the three options presented above are tabulated below:

Option	Pros	Cons
1. Do Nothing	<ul style="list-style-type: none"> No effort involved 	<ul style="list-style-type: none"> Loss of control Erosion of brand identity Tarnished public image of recycled water
2. Distinguish Recycled Water from Graywater	<ul style="list-style-type: none"> Control of message Protection of brand Public education 	<ul style="list-style-type: none"> Potential hostility from the graywater industry Possible resistance from some member agencies
3. Accept Properly Treated Graywater	<ul style="list-style-type: none"> Logical and familiar 	<ul style="list-style-type: none"> none
4. Include Reuse of Graywater	<ul style="list-style-type: none"> Control of message Protection of brand Improved public perception Larger water reuse tent in the long term 	<ul style="list-style-type: none"> Possible reluctance of graywater industry to collaborate Possibly confused public health message by supporting use of untreated wastewater by untrained individuals.

Action Items Under Each Option

Possible action items implied by each option are listed below:

Option	Action Items
1	None
2	<ul style="list-style-type: none"> Deliver Documentation and Clear Messages to Members and the Public Sponsor Legislation to Restrict Improper Use of Graywater Work with IAPMO and Others to Influence Future Versions of UPC, IPC, etc. Support Research in Relative Risks of Graywater Reuse
3	<ul style="list-style-type: none"> Include Treated Graywater in the Water Reuse Toolbox, on Equal Footing with Recycled Water of the Same Quality
4	<ul style="list-style-type: none"> Include All Graywater Into the Mission of WateReuse Association Form Graywater Committee of the Board Invite Membership from Graywater Industry Support Research in Various Aspects of Graywater Reuse Provide Educational Materials Regarding Safe Graywater Reuse

Approaching Government

States with plenty of water resources (those in the northern tier) have shown no need for regulating, encouraging, or even allowing graywater reuse. If the global climate change should result in greater water supply availability in a certain region, it can be expected that interest in graywater will wane rapidly in that region. Unfortunately, it appears that the opposite will be the case. [Australia just went through a 12-year period of continuous drought and the use of recycled water, graywater, and rainwater harvesting increased dramatically, along with one of the most thorough regulatory framework for their use.] If the California trend toward simplification and permissiveness of graywater regulation is any indication, it can be expected that other states will eventually follow suit and allow residents to reuse graywater onsite with minimal government intervention.

WateReuse Association, with an established policy direction, can play a positive role in shaping regulations and standards for safe graywater reuse no matter which policy option is adopted.

Approaching Industry

Irrespective of which policy option is selected, the water reuse industry should expand its proactive leadership toward IAPMO, pipe manufacturers, graywater purveyors, and other groups with an interest in graywater issues. This can be accomplished with active participation by member utilities and Association officers in select proceedings of the industries involved in graywater, code writing, and related activities. Liaison membership in such entities can be very helpful to represent the industry's interests and provide early warning of trends that may be inimical to the water reuse industry.

The February 1, 2010 deadline for proposals for changes to the 2009 UPC is an opportunity that should be seized to ensure that the purple pipe designation for all non-potable water is revised for graywater (and condensate, rainwater, etc.) to black or brown.

GRAYWATER WITHIN THE MUNICIPAL WATER RECYCLING FRAMEWORK

Recommendations to WateReuse Board of Directors

It is recommended that this paper be expanded as a public document with more exhaustive information about the experience of states (and other countries) that have had graywater experience for a number of decades. The timing of such an expanded document may best be after completion and release of the WERF/SDA study report of the long-term impacts of graywater.

An important action item for the Association would be to continue its close collaboration with WEF and AWWA and prepare the necessary documentation by February 1, 2010 to propose revision of the UPC and IPC color designation for alternative water sources from purple to black or another suitable color.

Future Research

The WateReuse Foundation should support future research in various aspects of graywater reuse, including

- A national database of actual use of graywater systems, including variations of penetration of graywater systems in communities correlated with demographic characteristics of those communities.
- Impacts of graywater use on water supply and wastewater management utilities in several selected communities.
- Public attitudes toward graywater—distinct from and contrasted with public attitudes toward recycled water.
- Quantitative risk assessment of various types of graywater reuse and comparative risk evaluation of graywater and several types of reclaimed water as used for different purposes.

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APPENDIX A PURVEYORS OF GRAYWATER SYSTEMS

The information contained in this Appendix is obtained from several sources and may not be complete, accurate, or up-to-date. The list of graywater system designers, installers and purveyors is presented merely for perspective.

- **Art Ludwig** (Large Scale Greywater Design) **Oasis Design 805 967-9956**; 5 San Marcos Trout Club Santa Barbara, CA 93105-9726, www.oasisdesign.net
- **AQUSTM** system by WaterSaver Technologies is U.S. based and can reduce metered water usage in a two-person household by about 10-20 gallons a day- or approximately 5,000 gallons a year. This system costs \$295 plus shipping. www.watersavertech.com
- The **Brac Greywater Recycling System** was designed in Canada and is built for residential use. This system reuses graywater saving approximately one third of home water consumption. It can be purchased in the U.S. from private retailers. Costs range from \$2,000 to \$3,000 plus shipping. www.bracsystems.com/home.html
- The **ReWater® system** captures, filters, and reuses shower, tub, bathroom sink, and laundry water. ReWater systems are available in the U.S. Costs range from \$2,000 to \$8,000 <http://www.rewater.com/>
- **AquaCycle of PONTOS** provides water treatment with a four-phase water treatment with UV light disinfection. The recycled water conforms to the European Directive 76/160EWG for Recreational Water. This product is offered by Hansgrohe in Germany. http://www.hansgrohe-int.com/int_en/86083.htm
- **Ecoplay** is a water management system which collects and cleans bath and shower water so it can be reused for flushing the toilet. Ecoplay systems are based in the Netherlands. <http://www.ecoplay-system.com/>
- The **Aqua Reviva** is a graywater treatment system. Design allows graywater to be used to the full extent of the law and is self-contained. The system is built so that if it malfunctions, it will divert water directly to the sewer. This system is being offered in Australia. <http://www.aquareviva.com.au/>
- The **Perpetual Water - Home® System** is a fully automated treatment system that saves and reuses up to 67% of household water, for use in the garden or back through the home. This product is offered in Australia. <http://www.perpetualwater.com.au/>
- The **Nylex Greywater Diverta** captures graywater for immediate reuse of shower, bathroom sinks, laundry sinks, and washing machines. This product helps in reducing demand for main water supply. It costs \$187 plus shipping and taxes. This product is offered in Australia. <http://www.enviro-friendly.com/nylex-greywater-diverta.shtml>
- The **Home Water Bowser Grey Water Wheelie Bin** captures water from the washing machine or can be used for rainwater collection. Costs range from \$429 to \$479. This system comes with a four meter inlet hose for the washing machine and a twenty meter outlet hose for watering the garden. This product is offered in Australia. <http://www.enviro-friendly.com/grey-water-bowser.shtml>

- The **Eco-Care Grey Waste Water Diverter System** diverts graywater where needed through a pump. It costs \$890 plus delivery. Eco-Care fully complies with EPA and DHS guidelines. If the system is not used in 24 hours, the tank automatically dumps the waste water. This product is offered in Australia. <http://www.enviro-friendly.com/eco-care-grey-water.shtml>
- The **NETA H2grO Grey Water Diverter System** is designed for when you need more than the standard 50 mm. inlet, and you want the unit to go in the ground. It diverts water to your garden for irrigation. Price ranges from ~\$2090.00 for the manual system to \$3300.00 for the electric diverter. <http://www.enviro-friendly.com/neta-h2gro-grey-water.shtml>
- **Technicians for Sustainability** 520 740-0736, Lisa Lucking Hoffman or Kevin Koch www.techniciansforsustainability.com
- **Desert Sky Home Repair, LLC** 520-622-0607, PO Box 1765, Tucson, AZ 85702,
- **Guy Cloutier** 991-4930
- **Harrington Company** 4141 E. Tennessee Ave 745-8433, Hose, pipe, fittings for adapting tanks and culverts for rainwater storage and delivery.
- **Plumbing Suppliers, Inc.** 2555 E. Grant Road 326-6433, Flow Splitter parts
- **Irrigation & Sprinkler Supply Company** Grey pipe for conveyance of graywater, 2130 E. 12th St. 792-4652, 5120 N. La Cholla 292-6900
- **Catalina Spas and Pools** 4001 N. Runway Dr. 888-4181, 3-way Jandy valves
- **Any pool and spa supplier**, Flexible hose & 3-way Jandy valve
- **Technicians for Sustainability** 520 740-0736, Kevin Koch or Lisa Lucking Hoffman
- **Brad Lancaster** <http://www.harvestingrainwater.com/>
- **Barbara Rose** (Residential & Community Design) 572-7221

APPENDIX B ALLOWED USES OF RECYCLED WATER IN CALIFORNIA

This summary is prepared for **WaterReuse Association**, from the December 2, 2000, Title-22 adopted **Water Recycling Criteria**, and supersedes all earlier versions.

<i>Use of Recycled Water</i>	Treatment Level			
	Disinfected Tertiary Recycled Water	Disinfected Secondary-2.2 Recycled Water	Disinfected Secondary-23 Recycled Water	Undisinfected Secondary Recycled Water
<i>Irrigation of:</i>				
Food crops where recycled water contacts the edible portion of the crop, including all root crops	Allowed	Not allowed	Not allowed	Not allowed
Parks and playgrounds	Allowed	Not allowed	Not allowed	Not allowed
School yards	Allowed	Not allowed	Not allowed	Not allowed
Residential landscaping	Allowed	Not allowed	Not allowed	Not allowed
Unrestricted-access golf courses	Allowed	Not allowed	Not allowed	Not allowed
Any other irrigation uses not prohibited by other provisions of the California Code of Regulations	Allowed	Not allowed	Not allowed	Not allowed
Food crops, surface-irrigated, above-ground edible portion, and not contacted by recycled water	Allowed	Allowed	Not allowed	Not allowed
Cemeteries	Allowed	Allowed	Allowed	Not allowed
Freeway landscaping	Allowed	Allowed	Allowed	Not allowed
Restricted-access golf courses	Allowed	Allowed	Allowed	Not allowed
Ornamental nursery stock and sod farms with unrestricted public access	Allowed	Allowed	Allowed	Not allowed
Pasture for milk animals for human consumption	Allowed	Allowed	Allowed	Not allowed
Nonedible vegetation with access control to prevent use as a park, playground or school yard	Allowed	Allowed	Allowed	Not allowed
Orchards with no contact between edible portion and recycled water	Allowed	Allowed	Allowed	Allowed
Vineyards with no contact between edible portion and recycled water	Allowed	Allowed	Allowed	Allowed
Non food-bearing trees, including Christmas trees not irrigated less than 14 days before harvest	Allowed	Allowed	Allowed	Allowed
Fodder and fiber crops and pasture for animals not producing milk for human consumption	Allowed	Allowed	Allowed	Allowed
Seed crops not eaten by humans	Allowed	Allowed	Allowed	Allowed
Food crops undergoing commercial pathogen-destroying processing before consumption by humans	Allowed	Allowed	Allowed	Allowed
Ornamental nursery stock, sod farms not irrigated less than 14 day before harvest	Allowed	Allowed	Allowed	Allowed
<i>Supply for impoundment:</i>				
Nonrestricted recreational impoundments, with supplemental monitoring for pathogenic organisms	Allowed**	Not allowed	Not allowed	Not allowed
Restricted recreational impoundments and publicly accessible fish hatcheries	Allowed	Allowed	Not allowed	Not allowed
Landscape impoundments without decorative fountains	Allowed	Allowed	Allowed	Not allowed
<i>Supply for cooling or air conditioning:</i>				
Industrial or commercial cooling or air conditioning involving cooling tower, evaporative condenser, or spraying that creates a mist	Allowed***	Not allowed	Not allowed	Not allowed
Industrial or commercial cooling or air conditioning not involving cooling tower, evaporative condenser, or spraying that creates a mist	Allowed	Allowed	Allowed	Not allowed
<i>Other uses:</i>				
Groundwater Recharge	Allowed under special case-by-case permits by RWQCBs****			
Flushing toilets and urinals	Allowed	Not allowed	Not allowed	Not allowed
Priming drain traps	Allowed	Not allowed	Not allowed	Not allowed
Industrial process water that may contact workers	Allowed	Not allowed	Not allowed	Not allowed
Structural fire fighting	Allowed	Not allowed	Not allowed	Not allowed
Decorative fountains	Allowed	Not allowed	Not allowed	Not allowed
Commercial laundries	Allowed	Not allowed	Not allowed	Not allowed
Consolidation of backfill material around potable water pipelines	Allowed	Not allowed	Not allowed	Not allowed
Artificial snow making for commercial outdoor uses	Allowed	Not allowed	Not allowed	Not allowed
Commercial car washes, not heating the water, excluding the general public from washing process	Allowed	Not allowed	Not allowed	Not allowed
Industrial process water that will not come into contact with workers	Allowed	Allowed	Allowed	Not allowed
Industrial boiler feed	Allowed	Allowed	Allowed	Not allowed
Nonstructural fire fighting	Allowed	Allowed	Allowed	Not allowed
Backfill consolidation around nonpotable piping	Allowed	Allowed	Allowed	Not allowed
Soil compaction	Allowed	Allowed	Allowed	Not allowed
Mixing concrete	Allowed	Allowed	Allowed	Not allowed
Dust control on roads and streets	Allowed	Allowed	Allowed	Not allowed
Cleaning roads, sidewalks and outdoor work areas	Allowed	Allowed	Allowed	Not allowed
Flushing sanitary sewers	Allowed	Allowed	Allowed	Allowed

* Refer to the full text of the December 2, 2000 version of Title-22: California Water Recycling Criteria. This chart is only an informal summary of the uses allowed in this version.

The complete and final 12/02/2000 version of the adopted criteria can be downloaded from: <http://www.dhs.ca.gov/ps/dwem/publications/Regulations/recycleregs_index.htm>

** With "conventional tertiary treatment". Additional monitoring for two years or more is necessary with direct filtration.

*** Drift eliminators and/or biocides are required if public or employees can be exposed to mist.

**** Refer to Groundwater Recharge Guidelines, available from the California Department of Health Services.

Prepared by Bahman Sheikh and edited by EBMUD Office of Water Recycling, who acknowledge this is a summary and not the formal version of the regulations referenced above.

APPENDIX C PERCENT OF US HOUSEHOLDS REUSING GRAYWATER

Alabama	1.3	Montana	0.2
Alaska	NA	Nebraska	0.8
Arizona	3.6	Nevada	0.4
Arkansas	1.5	New Hampshire	0.5
California	13.9	New Jersey	1.8
Colorado	1.6	New Mexico	0.9
Connecticut	0.4	New York	4.9
Delaware	0.1	North Carolina	1.6
Washington, District of Columbia	0.2	North Dakota	0.3
Florida	6.1	Ohio	4.0
Georgia	2.2	Oklahoma	1.2
Hawaii	NA	Oregon	1.6
Idaho	0.4	Pennsylvania	7.9
Illinois	2.4	Rhode Island	0.04
Indiana	1.6	South Carolina	1.1
Iowa	0.9	South Dakota	0.3
Kansas	0.5	Tennessee	2.0
Kentucky	1.7	Texas	11
Louisiana	1.1	Utah	0.5
Maine	0.8	Vermont	0.2
Maryland	2.2	Virginia	1.8
Massachusetts	1.2	Washington	2.6
Michigan	2.6	West Virginia	1.1
Minnesota	1.6	Wisconsin	2.4
Mississippi	0.9	Wyoming	0.2
Missouri	1.7	USA	7.0

SOURCE: Soap and Detergent Association 1999 Graywater Awareness and Reuse Study, Based on Screener data - Total Answering Screener = 61,377, Graywater Reusers = 2,416, NA = Data are not available

APPENDIX D. CALCULATIONS IN SUPPORT OF FIGURE 2

	2000	2030
Number of US Households	117,306,811	144,210,039
Number of California Households	12,736,312	16,182,878
US Percent Using Graywater	7.0%	10%
CA Percent Using Graywater	13.9%	25%
US Households Using Graywater	8,211,477	14,421,004
CA Households Using Graywater	1,770,347	4,045,720
Graywater Reuse per Household, Low (gpd)	40	22
Graywater Reuse per Household, High (gpd)	100	75
Total Daily Graywater Diversion, US, High Estimate (mgd)	821	1,154
Total Daily Graywater Diversion, US, Low Estimate (mgd)	328	433
Total Daily Graywater Diversion, CA, High Estimate(mgd)	177	324
Total Daily Graywater Diversion, CA, Low Estimate (mgd)	71	121

Assumed Data and Sources

Basic Data	Assumed Values	Source of Data, Projection
Population of US, 2008	303,824,640	CIA Estimate ³⁵
Population of US, 2030	373,504,000	US Census Bureau ³⁶
People per Household, US, 2000	2.59	US Census Bureau ³⁷
Households with Graywater Systems, US, 1999	7.0%	Soap and Detergent Manufacturers Association ³⁸
Population of California, 2007	36,553,215	US Census Bureau ³⁹
Population of California, 2030	46,444,861	US Census Bureau ⁴⁰
People per Household, CA, 2000	2.87	US Census Bureau ⁴¹
Households with Graywater systems, CA, 1999	13.9%	Soap and Detergent Manufacturers Association ⁴²

SOURCE: Adapted and Modified from Oasis Design Website:
<http://www.oasisdesign.net/greywater/law/california/index.htm>

³⁵ <https://www.cia.gov/library/publications/the-world-factbook/print/us.html>

³⁶ <http://www.census.gov/population/www/projections/summarytables.html>

³⁷ <http://quickfacts.census.gov/qfd/states/06000.html>

³⁸ http://www.sdascience.org/index.php?option=com_content&task=view&id=96&Itemid=131

³⁹ <http://quickfacts.census.gov/qfd/states/06000.html>

⁴⁰ <http://www.census.gov/population/www/projections/projectionsagesex.html>

⁴¹ <http://quickfacts.census.gov/qfd/states/06000.html>

⁴² http://www.sdascience.org/docs/Graywater_Habits_&_Practices_Survey.pdf p. 14

APPENDIX E. SUMMARY OF STATES' GRAYWATER REGULATIONS

SOURCE: Modified from Tabulations in Texas Onsite Wastewater Treatment Research Council, "Graywater Literature Search", circa 2004.

STATE	AGENCY	TITLE/CHAPTER	WEBSITE	APPLY TO RESIDENTIAL ?	LIMITS	APPLY TO COMMERCIAL?
ALABAMA	Alabama Department of Public Health, Environmental Services	Onsite Sewage Disposal Subdivision	www.adph.org/environmental/onsitesewage.pdf	Yes	N/A	Yes
ARIZONA	Arizona Department of Environmental Quality	R18-9-701 ADEQ Administrative Code	www.sosaz.com/public_services/title_18/18-09.htm	Yes	N/A	Yes
ARKANSAS	Arkansas Department of Health Sanitary Division	Alternate Systems Manual	www.healthysarkansas.com/rules_regs/general_sanitation.pdf	Yes	N/A	Yes
CALIFORNIA	California Department of Water Resources, Water	California Plumbing Code, Appendix	www.cwue.water.ca.gov/docs/Revised_Graywater_Standards.pdf	Yes	N/A	Yes
COLORADO	California Building Standards Commission	California Plumbing Code (Title 24, Part 5, Chapter 16A,	http://www.bsc.ca.gov/prpsd_chngs/pc_emrrm.htm	Yes	250 gpd	No
CONNECTICUT	Connecticut Department of Public Health	Disposal Systems		Yes	N/A	Yes
FLORIDA	Florida Department of Health, Bureau of Onsite Sewage Programs	Public Health Code Regulations & Technical Standards	www.dep.state.ct.us/dph	Yes	75	Yes
GEORGIA	Georgia Department of Human Resources, Division of Public Health	Public Health Chapter 381.0065; Florida Administrative Code 64E-6	www.doh.state.fl.us/Environment/OSTDS/pdf/files/forms/64e6.pdf	Yes	>500	Yes
HAWAII	Hawaii Department of Health, Wastewater Branch	Department of Human Resources Ch 290-5-26	www.state.ga.us/rules/index.cgi?base=290/5/26	Yes	150	Yes
IDAHO	Idaho Division of Environmental Quality	TITLE 11 Department Of Health - Chapter 62 Wastewater Systems	www.hawaii.gov/doh/rules/11-62.pdf	Yes	N/A	No
KENTUCKY	Kentucky Department of Public Health, Protection and Safety Division	IDAPA 16.01.03 Rules for Individual/Subsurface Sewage Disposal Systems	http://www.deq.state.id.us/waste/tgm-master_jan01.pdf	No	N/A	No
MAINE	Maine Department of Human Services, Bureau of Health, Division of Health Engineering	902 KY Administrative Regulations 10:085	http://chs.ky.gov/publichealth/environmental.htm	Yes	N/A	No
MARYLAND	Maryland Department of the Environment, Water Management Administration	1509.0 Separated Laundry Disposal Systems	www.yorkmaine.org/planboard/mestate_subsurface_waste_water_disposal_rules.pdf	No	N/A	No
MASSACHUSETTS	Massachusetts Department of Environmental Protection	Innovative and Alternative Program	www.dsd.state.md.us/comar	Yes	10000	No
MICHIGAN	Michigan Department of Environmental Quality, Health and Water	310 CMR 15.000, Title 5: Innovative and Alternative Systems	www.state.ma.us/dep/brp/www/t5itprog.htm	Yes	N/A	Yes
MINNESOTA	Minnesota Pollution Control Agency/Water Quality	Act 421 P.A., Acceptable Alternative Graywater Systems	www.weblife.org/humanure/appendix3	Yes	1000	Yes
		Chapter 7080.9010 Alternative/Experimental Systems	www.revisor.leg.state.mn.us/arule/7080	Yes		

APPENDIX E, continued. SUMMARY OF STATES' GRAYWATER REGULATIONS

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ST#				RESIDENTIAL ?		TO COMMERCIAL ?
MONTANA	Department of Environmental Quality	DEQ 4	http://www.deq.state.mt.us/wqinfo/Sub/Index.asp	No	N/A	No
NEVADA	Dept. of Human Resources	R.129-98 Sewage Disposal Administrative code	www.leg.state.nv.us/Register/R129-98Adopted.html	Yes	N/A	Yes
NEW JERSEY	Department of Environmental Protection	N.J.Administrative Code 7:9A	www.state.nj.us/dep/dwq/pdf/njac79a.pdf	Yes	75% of black water	Yes
NEW MEXICO	Environment Department	House Bill 114	http://legis.state.nm.us (use bill finder for 114)	Yes	250	No
NEW YORK	Department of Health	10NYCRR Appendix 75-A	www.dec.state.ny.us/website/ppu/grnbldg/gbprop.pdf	Yes	75 gpd/bedroom	No
NORTH DAKOTA	ND dept of Health Environmental Health Division	Ch. 62-03-16-01individual sewage treatment	www.weblife.org/humanure/appendix3	Yes	N/A	Yes
OREGON	Dept of Environmental Quality Water Quality Division	OR administrative rules ch918 division 790	www.cbs.state.or.us	Yes	N/A	Yes
PENNSYLVANIA	Dept of Environmental Protection Bureau of Water Quality	Title 25 Environmental protection CH.73	www.weblife.org/humanure/appendix3	Yes	N/A	Yes
RHODE ISLAND	Dept of environmental management	Ch. 12-120-002		No	N/A	No
SOUTH DAKOTA	Department of Environment and Natural Resources	Administrative Rule: ARSD 74:53 Water Supply and Treatment Systems. Specifically, sections 74:53:01:38 and 74:53:01:19	http://legis.state.sd.us/rules/rules/7453.htm	Yes	minimum of 25 gal/day/person	Yes
TEXAS	Texas Commission On Environmental Quality	Existing rules under 30 TAC, Chp. 285, Subchapter H. Currently working on a set of rules to fulfill HB 2661	www.tceq.state.tx.us/oprd/rules/pdfib/285h.pdf	No	N/A	No
WASHINGTON	Department of Ecology	Publication No. 98-37 WQ; Section E1		Yes	N/A	Yes
WISCONSIN	Department of Commerce	Chapter Comm 82, Wis. Adm. Code; specifically Comm 82.34, 82.40, 82.41, and 82.70	http://www.legis.state.wi.us/rsb/code/codtoc.html	No	N/A	No