WHITE PAPER

ON

GRAYWATER

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Preserving & Enhancing the Global Water Environment

WATEREUSE ASSOCIATION

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Notes on Word Usage

The words "recycling" and "reclamation" and "recycled" and "reclaimed" and their derivatives are used synonymously and interchangeably in this document, in recognition of the common usage of each set of words in different regions of the country and the world.

The spelling of "graywater" in this document follows the most common U.S. practice. In other publications, alternative spellings such as "gray water", "greywater", and "grey water" are frequently used. Where such publications are quoted directly in this White Paper, the authors' original spellings are used unchanged.

EXECUTIVE SUMMARY

- Graywater reuse is viewed by the green-leaning layperson as the panacea for water shortages, groundwater depletion, surface water contamination, and climate change.

- 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 for the more complex systems exceeds 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 nonexistent. While this absence of documentation 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.

SCOPE OF WHITE PAPER

This white paper is sponsored jointly by the

- WateReuse Association (WRA),
- Water Environment Federation (WEF), and
- American Water Works Association (AWWA).

The White Paper is intended to help the Board of Directors of the 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.

Graywater reuse is prevalent mainly in the semi-arid regions in the West and the South, but it is not as common 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 shortages. Thus, the impact of increased graywater reuse, if any, can 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, bathwater 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 wastewater after diversion of graywater than before, with little or no impact on the carrying capacity of the sewers and on the ability of the biological processes in the treatment plant. However, the impact of reduced flow, when combined with 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 resuspension.

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 all types of graywater reuse 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 (for example, an epidemic of cholera) related to graywater reuse intensified with the 2009 adoption by the International Association of Plumbing and Mechanical Officials (writers of the Uniform Plumbing Code, International Plumbing Code, and other building and mechanical codes) to designate purple as the color for identification of pipes carrying all types of nonpotable 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 nonpotable 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 ft 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 reuse and to associate that goodwill with all varieties of 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 for swaying 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 "blackwater." Exclusion of toilet waste does not necessarily prevent fecal matter and other human waste from entering the graywater system—albeit in small quantities. Examples of routes for such contamination include shower water and bathwater and washing machine discharge after cleaning of 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 dishwashers. (California Building Standards Commission, 2009)

This definition assumes that the homeowner would take extraordinary care in source control of contaminants and ensure 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 an 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 windblown 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 or include a soil absorption basin, 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 some—as is condensate from refrigeration equipment, collected stormwater, and other nonpotable water sources that have not been contaminated with human waste. Nonetheless, for the purposes of this paper, they are considered 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. Therefore, the emphasis in this paper is on residential and commercial graywater, although many of the conclusions and recommendations are equally applicable to all alternative sources of nonpotable water.

Treated Graywater Systems

Graywater from nontoilet, nonkitchen sources at a high-rise building, a sports stadium, or an apartment house is sometimes collected separately and treated in an onsite wastewater treatment plant. Blackwater is collected in a separate sewer and sent to the central treatment plant. Effluent from the onsite treatment system is then utilized as nonpotable recycled water in a manner similar to that for recycled water. The rationale for such systems is that (a) graywater sources within the building provide enough water for the nonpotable water demand in the building and its vicinity and (b) the lower solid 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 3000 m^2 or over 5000 m^2 (depending on local regulations) of usable space are required to provide onsite treatment and reuse—mainly for toilet flushing. These graywater systems utilize highly sophisticated treatment systems, including membrane biological reactors, and are closely monitored.

Treated graywater systems are not in common use in the United States at the present time; however, the advent of Leadership in Energy and Environmental Design (LEED) certification and of other sustainability incentives is expected to increase their utilization in the future. Treated graywater that meets 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 provided by homeowners, are common and do not necessarily provide adequate safeguards for those exposed to the water. These simple graywater systems rely on the aerobic topsoil's capability to provide additional treatment by decomposing organic matter and deactivating the microorganisms in graywater.

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 and in replacement of 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 to individuals engaged in promotion of graywater reuse and dissemination of information in its support. Surprisingly, the number of purveyors of treated 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 nonpotable 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 the International Association of Plumbing and Mechanical Officials (IAPMO) have indicated that the primary issue is public health protection from cross-connections and potential exposure to water of lower quality. This concern would apply to contamination of potable water or to 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 following:[1]

- 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 wastewater treatment plants (WWTPs), impairing the reliable production of recycled water;
- Public, media, and elected officials' confusion of 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 the salinity of recycled water as a result of diversion of the lower-salinity bathwater, shower water, and lavatory wastewaters from the sewer.

[1]These statements are neither exhaustive nor necessarily wholly accurate, nor are they representative of the 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 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 (for example, Rose et al., 1991; Siegrist, 1977; Casanova et al., 2001) and unpublished reports on pilot projects conducted for graywater reuse (for example, 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 on an intensive program of research into long-term graywater reuse, its characteristics and its effects on human health and the environment and a report of the first phase of this collaborative effort, primarily a literature search, has been published (Roesner et al., 2006).

A second phase of the WERF/SDA project is under way, with scientists performing controlled field research and characterizing existing sites of 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), the owners of all of which have been using graywater to irrigate their landscapes for more than 5 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 higher-risk wastewater. Information from this study, expected to see publication in the spring of 2011, may 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. It shows the typical urban distribution of indoor water usage in the United States.

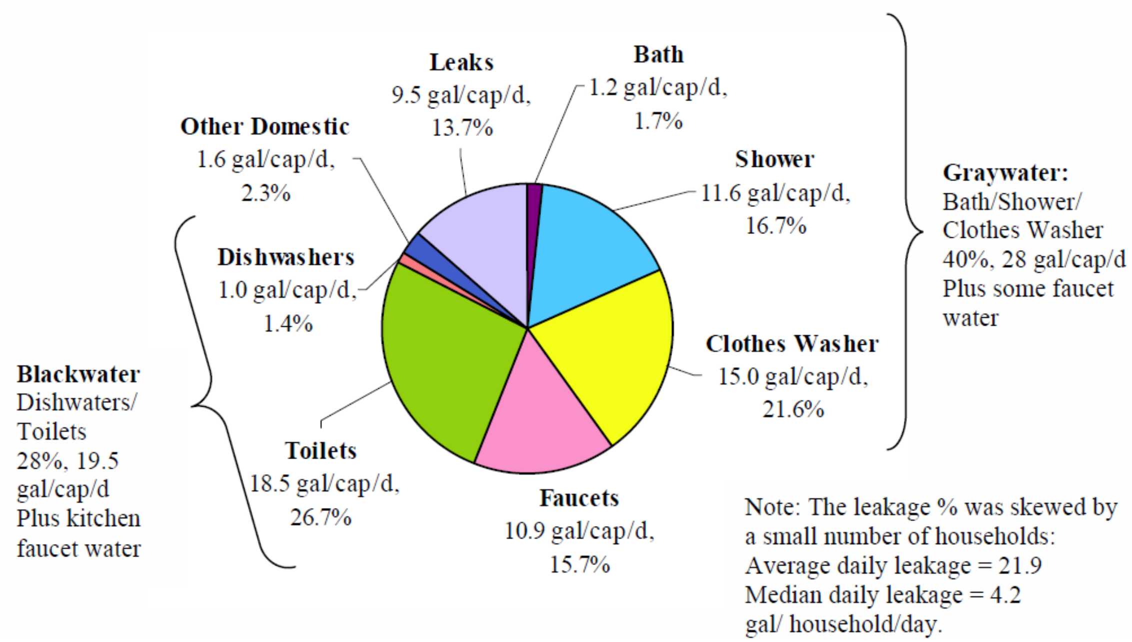

Figure 1. Average indoor residential water usage for 12 North American cities (Adapted from *Residential End Uses of Water* by permission. Copyright ©1999 American Water Works Association and AwwaRF, (AWWA 1999))

According to *Residential End Uses of Water* (AWWA, 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 percentages by state of households with graywater use.

According to the 1999 Soap and Detergent Association survey (The NPD Group, 1999), the average graywater system in the United States uses only 6.3 gpd.[2] This figure is far lower than the potential maxima calculated in Table 1 to provide the upper range of potential future graywater reuse.

Table 1. Maximum Graywater Generation Rates in Typical U.S. Households[a]

Source or Total	% of Indoor Use	Graywater Generation Rate		
		Gal/per capita/day	Gal/household/day, 1999	Gal/household/day, 2030 (est.)
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**

[a]First three columns are based on data in Figure 1.

[2]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 ethics 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 in a household, they 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. This higher efficiency is likelier to be attained by a treated graywater system—under pressure—than by a simple graywater system—under gravity. Potable water must be supplemented in almost all situations for the remaining demand not met with graywater. This argument is one of the most compelling for concern about cross-connection and backflow potential, discussed further in Part II of this paper.

Microbial Quality of Graywater

Various fecal coliform counts in graywater have been reported, ranging from thousands to millions of CFU/100 mL. 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[a]

Microbial Content	Data for: Siegrist, 1977 Laundry	Novotny, 1990	Rose et al., 1991	City of Los Angeles, 1992	Christova-Boal et al., 1996 bath	Casanove et al., 2001	Ottoson and Stenstrom, 2003
Total Coliform	10^2	10^7–10^8	2.5×10^7	10^4–10^5	2.3×10^3–3.3×10^5	1.9×10^8	1.3×10^8
Fecal Coliform	10^2	10^6–10^7	2.0×10^4–7.9×10^6	10^1–10^5	2.0×10^1–3.3×10^3	1.1×10^7	—
Fecal Enterococci				ND–1.6×10^4			2.5×10^4

[a]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 by various state regulations governing use of reclaimed or recycled water (for example, the California Water Recycling Criteria (CDPH, 2001) require total coliform levels of <2.2 MPN/100 mL for most urban uses) corresponding to a virtually pathogen-free source of water. Because of graywater's microbial content, states that do regulate and allow its 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 resource means a potentially big seasonal savings in water costs at the potable water meter. In some cases, it also means a concomitant savings in wastewater service costs for 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 cities of Tucson, Cottonwood, and Chino Valley, AZ, 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 task is neither simple nor 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 of 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 that capture 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 that 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 absence in part stems from 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 fewer than 2% of 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.

If one considers 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 California[3] and to reach 8 million in the United States (The NPD Group, 1999; Oasis Design, 2009). Assuming an average of 75.5 gpd per household, the maximum total daily diversion of graywater would amount to 128 mgd in California and 604 mgd in the United States. The higher California estimate and the US estimate are according to Art Ludwig, (Oasis Design 2009.) Comparing these figures with current municipal wastewater capacity yields a rounded figure of 4% for California. This diversion is not a significant amount of the wastewater that would otherwise end up at central treatment plants. In fact, wastewater flows from most wastewater collection systems are measured with a precision that is > ±4%.

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 onsite 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.

[3]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% of households have graywater, as opposed to 13.9%.

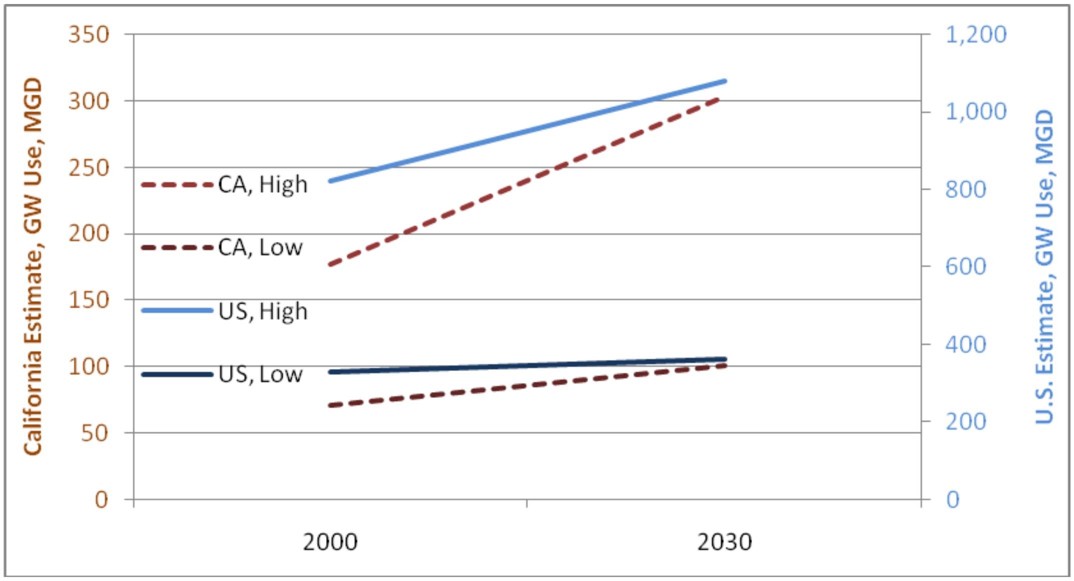

Figure 2. Estimated Growth in Graywater Reuse in California and in the United States under two Scenarios: (a) Low and (b) High Rates of Increase in Penetration of Graywater Reuse Systems.

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 were recently challenged in Colorado, but the Colorado legislature has favored allowing at least 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 June 2nd, 2009. The full text of the bill is at http://www.leg.state.co.us/Clics/CLICS2009A/csl.nsf/fsbillcont3/7EBE1FD8BEB4A0088725753C0061EF02?Open&file=1129_enr.pdf.

"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 allowed" (*Graywater Reuse*, 2009).

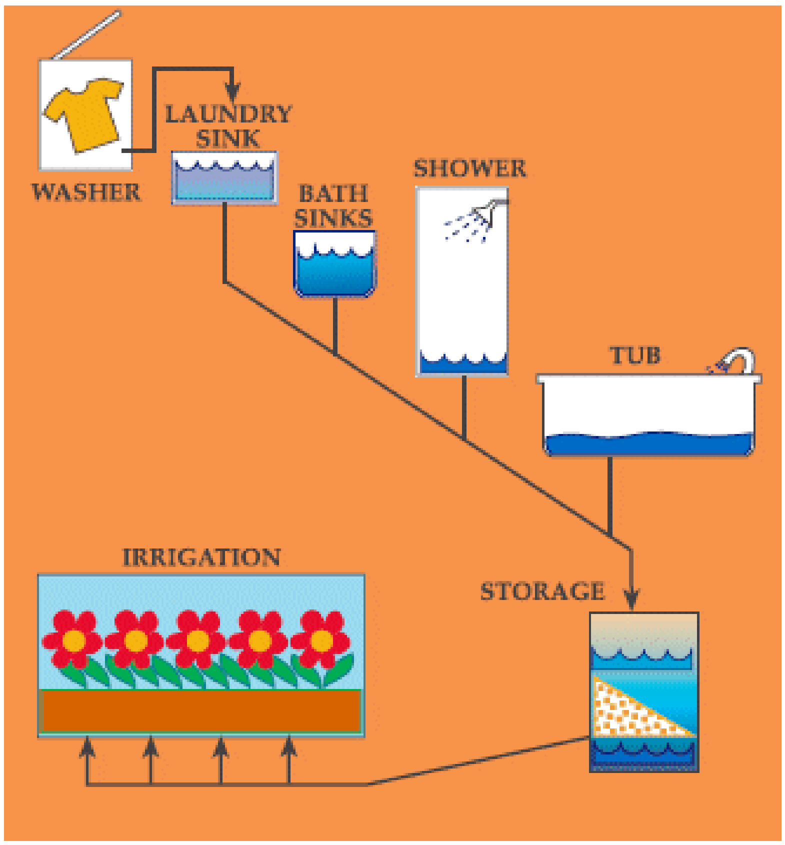

Figure 3. Sources of graywater for subsurface irrigation of landscape.
Source: Tucson Water, 2009.

PART II   GRAYWATER BACKGROUND

MOTIVATION FOR GRAYWATER REUSE

The motivation driving graywater reuse begins with the mind-set 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 responsibility 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 life cycle cost analysis for these actions, relying instead on a strong belief in the rightness of their actions and expecting repayment 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 use graywater 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 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" (BMPs) advanced by their water purveyors. Graywater reuse is indeed a rediscovery of a very ancient practice—one that went out of style because it was deemed unsanitary, potentially dangerous to public health, and needless because of the availability of cheap, seemingly limitless tap water and easy wastewater disposal. Each episode of drought in the past 50 years has brought about a surge of new advocates and users of graywater with various 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. Users of still more elaborate systems build a second drainage system in their residence to capture nearly all graywater sources and lead the water 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 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, about 0.01% of the 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 nontechnical 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. It is anticipated that the ranks of professional graywater installers will grow as regulations for more practical and safe systems are promulgated. 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 in., 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 users currently demand. 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—toward graywater reuse by homeowners and commercial entities.

According to a 1999 survey of single-family households in southern Arizona, 13% of the households reuse graywater (WATER CASA, 1999). This survey was completed 10 years ago, and the results may be no longer 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 occupied older houses, lower-value houses, houses for lower income levels, manufactured housing, and houses with 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 onsite 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 website (*Graywater and Rainwater Use*):

> Casa del Agua[4] 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

[4]Casa del Agua is now closed.

> 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 graywater 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 (Little, 1999).

The City of Tucson promotes a State of Arizona tax credit to graywater users as an incentive to encourage this practice (Tucson Water, 2009). This tax credit is in effect through 2011 (Little, 2009).

California

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 City Council instructed the Office of Water Reclamation to conduct a yearlong pilot study of graywater reuse in eight residences in various parts of the city. The report of that study (City of Los Angeles, 1992) 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 water savings are not expected to be significant. Los Angeles 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 (Cross, 2009). 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. Owners of a few high-end houses are installing approved graywater systems for indoor and/or outdoor use in order to become LEED certified. There could be other households that have installed these systems, but officials are not aware of them. Officials receive more inquiries on using rainwater-harvesting systems (cisterns to store rainwater) for outdoor and other nonpotable uses than they do graywater inquiries. And there are a large number of households in Sarasota County that have installed cisterns for supplementing irrigation water use. The reason graywater systems are not widespread in Florida may be that they are costly compared to other water conservation projects such as low-flow toilets, rain sensor installations, etc., which are very popular and successful (Musicaro, 2009). Also, Florida enjoys frequent rainfall and reliable reclaimed water service to over 250,000 households.

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 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 because those counties do not have reclaimed water systems, unlike Pinellas, Pasco and Hillsborough counties, which have regional reclaimed water systems (Musicaro, 2003).

Other States

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

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 structures 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 report (San Antonio Water System, c. 2004) from which the Appendix E tables were adapted.

Several states, including North Carolina (North Carolina Code, 2006), allow graywater reuse only if it is first treated to standards identical to those required for water reclamation from the complete wastewater stream (blackwater and graywater combined). In the following sections, the regulations or code standards of a few of the states—those with the most proactive (and generally more permissive) standards—are described.

Arizona

To make the process easier for those who want to reuse graywater at their homes, the Arizona Department of Environmental Quality developed graywater rules with stakeholder input (Arizona Department of Environmental Quality, 2007). Many of these rules are based on the results of a graywater study conducted in the Tucson area (Tucson Water, 2009). 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 (http://azdeq.gov/environ/water/permits/reclaimed.html). Although one need not apply for a formal permit to reuse graywater, the homeowner must abide by the 13 BMPs listed below, which were developed to protect public health and water quality:

1. First and foremost, avoid human contact with graywater or with 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 be used only in locations where groundwater is at least 5 ft below the surface.
7. Label pipes carrying graywater under pressure to eliminate confusion between graywater and drinking water pipes.
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 onsite wastewater disposal system, your graywater use does not change that system's design requirements for capacity and reserve areas.

The mayor and city council of Tucson, AZ, adopted an ordinance in September 2008 (City of Tucson, 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 graywater 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" (California Department of Water Resources, 1994) with step-by-step instructions on how to install a graywater system and how to 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 Design, Graywater Action (formerly called Graywater Guerrillas), and ReWater Systems, Inc. These purveyors/activists and a larger number of individuals have been lobbying the state legislature for a code provision friendlier to 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 (California Legislature, 2008). The legislators telegraphed their intent for a more permissive code with the following paragraph (California Legislature, 2008):

> "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."

> “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.”

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.

The new code (California Code, 2009) provides that simple graywater systems using only one fixture—such as a washing machine—do not require 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.
    a. **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.
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. (California Code, 2009) ”

The old provision for burial of graywater lines more than 9 in. below the soil surface was reduced to 2 in., 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 (Florida Code, 2007). Sections C101.1 to C103.11 cover all requirements for graywater recycling systems in Florida. It appears that graywater reuse law applies to both residential and commercial applications, although that stipulation 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 nonpotable 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 nonpotable 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 (Texas Code, 2005) 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 gal 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. do not provide easy 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 be used only

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 of 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 policy on graywater allows up to 250 gal of graywater per day 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 gal 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 those faced with the prospect of water rationing, steady increases in 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 of 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. Those higher levels 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 be unknowingly 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 common because of their locally economical features and their ability to produce recycled water at the location where demand for nonpotable 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 reuse. 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 (USGBC, 2010), developed by the U.S. Green Building Council (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 ft (99 km^2) of development area.

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, CO_2 emission reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts.

Developed by the USGBC, LEED provides building owners and operators a concise framework for identifying and implementing practical and measurable green building design, construction, and operation-and-maintenance solutions.

LEED is flexible enough to apply to all building types—commercial as well as residential. It works throughout the building life cycle—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.

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 indoors and through water-wise landscaping outdoors. 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 landscaping (Solaire, 2010) as well as use of recycled water for toilet flushing.

INFRASTRUCTURE

Plumbing Codes Pertaining to Graywater[5]

Several organizations develop and publish plumbing codes and building codes. Each jurisdiction selects the code it will 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 IAPMO and used by most jurisdictions as their own basic regulation for indoor plumbing in buildings. The International Plumbing Code (IPC) provides similar language for other jurisdictions that also requires purple pipe for nonpotable waters.

Since the mid-1990s, the UPC has included graywater as a source of water for irrigation of landscape—albeit with conditions that closely mimicked 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 UPC.[6] IAPMO approved the language, and it 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 provision includes graywater, harvested rainwater, air conditioner condensate, stormwater, and untreated surface water and groundwater. To individuals involved in municipally treated reclaimed water systems, the cause of immediate alarm was the use of purple pipe to deliver nonpotable 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 February 1, 2010, to qualify for the review and public comment cycle.

The revisions to the 2006 UPC simply changed the pipe color scheme 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, or green PVC pipe, as green designates wastewater piping to the water industry. For internal uses, such as toilet flushing, it is expected that the water quality requirements for graywater use would be identical to those for recycled water use and that, therefore, use of purple pipe would pose no confusion or conflict.

[5]Most of the text is this section is adapted from Vandertulip, 2009.
[6]The IPC follows a similar 3-year cycle of code revisions.

IAPMO members also active in the Society of Plumbing Engineers on the Plumbing Technical Committee did not want an additional use designation for yellow pipe, as yellow is used to designate flammable gas piping. This objection 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 nonpotable water sources. The issue is that there is no one monitoring the recirculating graywater quality, frequency of sampling, or the capability or certification of operators or maintenance of the systems.

Conflicts with State, Local Regulations

Conflict with Return-Flow Credit[7]

A major conflict exists where any wastewater is reused consumptively[8] and is 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, NV. Wastewater in the valley is collected and treated by three cities and the Clark County Water Reclamation District. A total of 190 million gal 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 pattern holds because the current discharge of wastewater effluents to the Las Vegas Wash already recycles all water used nonconsumptively (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 onsite 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" (Southern Nevada Water Authority, 2008).

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

[7] Most of the material in this section is taken almost directly from Rimer (2009a.)

[8] 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. Nonconsumptive 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.

drains to a storage (surge) tank, and thence to the landscaped area via irrigation pipes—normally black plastic pipes ending in spaghetti tubing feeding inline or terminal emitters. Conveyance of graywater on a larger scale may occur in a commercial or multiunit 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 few, 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 to convey reclaimed/recycled water. A potential conflict would be envisioned if the owner of a site with such access to recycled water were to use graywater also and piped it in purple 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—for example, an epidemic of cholera due to a "purple-pipe" transmission—it would be very difficult to explain the difference between gray water 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.[9] 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 designating purple for all alternative water sources.

Compatibility with Utilities' Practices and Standard Specifications

Designation of the color purple for pipes carrying all types of nonpotable 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 misconnections, cross-connections, and backflow.

[9]Based on data from Florida Department of Environmental Protection, 2007.

Storage of Graywater

Storage of graywater is often necessary because the timing of its production and that of its utilization are usually not the same—although there are some designs with no storage. Generally, a 50-gal (or smaller) storage tank is sufficient for a residential graywater system. It is not advisable to store graywater for more than 24 h, given 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 nonpotable and unsafe and may be dangerous if someone is exposed to it.

Distribution and Application Systems

Nearly all graywater is used onsite where it is generated. Usually, graywater is applied beneath the soil surface with drip irrigation emitters and nonclogging nozzles or in mulch-filled basins. 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 did not reflect concern 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, algal 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 may be carrying as many as four different types of nonpotable water, producing a high cross-connection potential. There also can 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 occurrence is rare, 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 (for example, "CAUTION: GRAYWATER—DO NOT DRINK") in English and Spanish or in 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:

- graywater is ponded on the surface of the soil or in a tub, bucket, etc.;
- the open end of a potable water hose is left submerged in the ponded water; and
- 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 on 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 problem 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 to use the stub-out and whether to 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 interior plumbing for a graywater system.

The new rules require interior plumbing—also called stub-outs—for graywater systems for all new houses 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 also would 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 prospective buyers.

> "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."

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 $1000. The more sophisticated systems offered on the market by specialized providers of such systems cost in the range of $2500 to $8000 (ReWater, 2010).

Potable Water Savings Potential

While at least one source has indicated that graywater reuse leads to increased water use,[10] 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 (City of Los Angeles, 1992) 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 normally would have been sent to the sewer, the household that uses graywater for irrigation and documents the quantity diverted to the wastewater utility's satisfaction can earn an additional benefit from reduced charges for wastewater treatment. However, if the utility adjusts the wastewater factor for the residences using graywater or does not recognize savings because 100% of the household wastewater still can be delivered to the organized collection system, this potential 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 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 for achieving sustainability goals. Graywater is no exception. In fact, graywater appears to be more favorably viewed by the public at large than are 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.

[10] This theory 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" quoted in a Southern Nevada Water Authority brochure (2009). It is attributed to Waterwise Rebate Scheme Review 2007, Data Analysis Australia Pty Ltd, April 2008, but a full reference is not given.

Cost-Effectiveness for the Homeowner/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. The 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), graywater recycling, including a disinfection and "electrochemical treatment step," can result in significant cost savings for homeowners and industry. However, other studies appear to conclude the opposite. The City of Los Angeles Office of Water Reclamation pilot study scientists 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 $5000. 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 a similar pilot study conducted by the California Department of Water Resources (Bennett et al., 2002) at three disparate sites, the costs of the systems installed far exceeded the value of the 20-year water savings. A simple benefit–cost analysis indicates that the monetary benefits alone did not justify the costs of these three systems, as indicated in Table 3.

Table 3. Simple Benefit–Cost Analysis

Graywater Test Location	Cost of Equipment	Value of Water Saved over 20 Yrs	Benefit/Cost Ratio	Payback Period (Yrs)
Santa Barbara	$1131	$893	0.79	25
Danville and Castro Valley	$5400	$895	0.17	120

Costs Avoided by the Community

Advocates of graywater claim that the community benefits from reduced demand on stressed water supplies and from a reduction of wastewater flow into treatment plants. No quantitative data have been provided to illustrate the extent of such costs avoided by 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, 2009a).

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 distribution system for recycled water has already invested a tremendous amount of resources (including energy and its CO_2 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 in fact will be maintained and sustained over the long term. At this point, the possibility is only speculative, 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.

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. In contrast, a graywater installation can be operational without any public involvement and with no assessment of its cumulative impacts. In a recent paper, Rimer (2009b) 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 maintaining it, 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 area merits future research.

In situations where the capital costs of collection system and wastewater treatment capacity are not reduced in order to enable receiving and treating graywater discharges, there may be no capital cost savings to society.

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 lower than in raw wastewater but far greater than the maximum levels allowed under current federal, state, and international standards for water uses involving human contact (drinking, bathing, park irrigation, etc.)

Thus, arguments against allowing widespread and uncontrolled use of graywater have been based on the microbial quality of graywater and on 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:

- 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 another possible source of pathogen transfer.

- Compliance with effective graywater regulations, minimizing exposure, may have been effective enough to prevent the majority of cases that otherwise would have arisen.

The investigators in charge of the long-term study of graywater reuse, currently ongoing under the joint sponsorship of the 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 as indicated by coliform bacterium counts 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 4.

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 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 but without a scientifically based foundation. Graywater advocates cite lack of documented diseases associated with graywater reuse. While the lack of documentation does not prove a 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. See Table 4.

Table 4. Incidence of Recorded Communicable Diseases in California with Potential and Recorded Linkage to Graywater, Extrapolated to the Last 60 Years[a]

Disease Potentially Linked to Graywater	No. of Cases in 2007	Est. No. of 60-Year Cumulative Cases	No. of Cases Linked to Graywater
Cholera	7	288	0
Cryptosporidiosis	11,170	502,650	0
E. coli, Shiga toxin-producing	4847	218,115	0
Giardiasis	19,417	873,765	0
Hepatitis A	2979	134,055	0
Legionellosis	2716	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**

[a]This summary table is extracted from a larger tabulation of graywater data compiled by Oasis Design, ©2009. Available at California Graywater Policy Center, 2009. Reproduced/adapted with permission from Art Ludwig.

Another important consideration about risk 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 versus exotic risk. Consider the outrage toward terrorism and murder 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 lack of proficiency 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 in a conceptual tabulation, as reproduced with minor modifications in Table 5.

Table 5. Conceptual Analysis of Range of Risk from Graywater Reuse[a]

Risk Factor	Characteristics of Those at:		
	Lower Risk	Intermediate Risk	Higher Risk
Population	Small (single-family)		Large (multiple 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

[a]Adapted from Dixon et al., 1999.

A screening-level quantitative microbial risk assessment (QMRA) was undertaken by Ottoson and Stenstrom (2002) for rotavirus, *Salmonella enterica* serovar 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.

- Accidental ingestion of 1 mL of treated graywater.
- Yearly risk from direct exposure after irrigation with graywater, assuming 1-mL intake/day and 26 days/year.
- 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 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 microorganisms 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 microorganism, *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 (namely, 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 that 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 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 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 that the general public now holds a positive image of graywater reuse. It remains to be seen whether 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. (1999) 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 desktop risk-assessment study sourced from current and long-standing published material on risk, graywater reuse, 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 reuse 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 factor 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 2 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. Many 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 views graywater positively, combined with the inability of most to 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 reimages 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 extent of reduction of flow to water reclamation plants must be calculated individually and separately for each community, a process that would be aided by a survey of penetration rates 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. The Arizona experience is that retrofitting the existing housing stock to capture graywater will not be sufficient to significantly impact the sewer flows in built-out neighborhoods; at best, a small portion of homeowners will access their laundry water (Little, 2009.)

Carrying Capacity of Sewers for Suspended Solids

Total-suspended-solid (TSS) content of domestic wastewater typically falls 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 concentration is still extremely dilute and not necessarily conducive to deposition by itself. However, the effect of reduction of flow in the sewer line by half on velocity of flow is more important in determining whether 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% 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' water, and 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 experience only a relatively small reduction in overall flow because of the relatively low percentage of dwellings using graywater systems in the community. In Arizona, new developments are required to adapt slope and pipe diameters in new infrastructure to better accommodate reduced sewer flows that are occurring and will occur not only from graywater reuse but from increasingly efficient fixtures and appliances too (Little, 2009).

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, namely, from laundry soaps and personal care products from the lavatories and baths. This removal may have a beneficial impact on the mineral quality of water reclaimed from the remaining wastewater stream. The higher concentration of TSSs 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

The WateReuse 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 those of the national organization in significant ways. This situation is healthy 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), while 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 the 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, to alert decision-makers about the risks inherent in exposure to untreated wastewater, and to distance the industry from graywater proponents and purveyors. The WateReuse Association would advise its members to inform themselves about the risks of reuse of untreated graywater and of 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

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, the WateReuse Association would encourage membership from the graywater industry members, along with proportional representation. The 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

Table 6 compares all four options discussed.

Table 6. Pros and Cons of the 4 Policy and Planning Options Presented Above

Option	Pros	Cons
1. Do nothing	• No effort involved	• Loss of control • Erosion of brand identity • Tarnished public image of recycled water
2. Distinguish recycled water from graywater	• Control of message • Protection of brand • Public education	• Potential hostility from the graywater industry • Possible resistance from some member agencies
3. Accept properly treated graywater	• Logic and familiarity	• None
4. Include reuse of graywater	• Control of message • Protection of brand • Improved public perception • Larger water reuse tent in the long term	• Possible reluctance of graywater industry to collaborate • Possible confusion of public health message by supporting use of untreated wastewater by untrained individuals.

Action Items under Each Option

Table 7 lists possible actions implied by each option discussed previously.

Table 7. Action Items Implied by Each Option

Option	Action Items
1	None
2	• 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	• Include Treated Graywater in the Water Reuse Toolbox on Equal Footing with Recycled Water of the Same Quality
4	• 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 global climate change should result in greater water supply availability in a certain region, it can be intuitively 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, accompanied by one of the most thorough regulatory frameworks 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.

The 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 goal 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 in representing the industry's interests and in providing 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 nonpotable 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 states (and other countries) that have had graywater experience for a number of decades.

An important action item for the Association would be to continue its close collaboration with the WEF and AWWA and to 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 to 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 their demographic characteristics.
- 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 Oasis Design** 805-967-9956. 5 San Marcos Trout Club, Santa Barbara, CA 93105-9726. Large-scale graywater design. www.oasisdesign.net

- **NUBIAN** Water Systems manufacture and install graywater treatment systems for single-family residential units, apartment blocks, hotels, schools, townhouses and commercial buildings. Solids separation removes lint and other coarse materials to prevent blockages and fouling of the system. Water flows down through a bed of proprietary media in the Processor. Contaminant removal is achieved through filtration, adsorption and biological treatment. Ultraviolet (UV) disinfection completes the treatment process before the treated water is stored for recycling. Nubian is headquartered in Silverwater, New South Wales, Australia and provides service in Western United States. Website: http://www.nubian.com.au/index.asp Contact phone number: + 61 2 9647 2633

- **AQUSTM** system by WaterSaver Technologies is U.S. based and can reduce metered water usage in a two-person household by about 10 to 20 gal a day—or approximately 5000 gal 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 United States from private retailers. Costs range from $2000 to $3000 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 United States. Costs range from $2000 to $8000. http://www.rewater.com/

- **AquaCycle of PONTOS** provides four-phase water treatment with UV light disinfection. The recycled water conforms to 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 that collects and cleans bathwater 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. The 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 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 from showers, bathroom sinks, laundry sinks, and washing machines. This product helps in reducing demand for the 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 4-m inlet hose for the washing machine and a 20-m 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 h, the tank automatically dumps the wastewater. 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 when you want the unit to go in the ground. It diverts water to your garden for irrigation. The price ranges from ~$2090 for the manual system to $3300.00 for the electric diverter. http://www.enviro-friendly.com/neta-h2gro-grey-water.shtml

APPENDIX B ALLOWED USES OF RECYCLED WATER IN CALIFORNIA

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

	Treatment Level			
Use of Recycled Water	Disinfected Tertiary Recycled Water	Disinfected Secondary-2.2 Recycled Water	Disinfected Secondary-23 Recycled Water	Undisinfected Secondary Recycled Water
Irrigation of:				
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**
Supply for impoundment:				
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
Supply for cooling or air conditioning:				
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
Other uses:				
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/ddwem/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 PERCENTAGE OF US HOUSEHOLDS REUSING GRAYWATER[a]

State	% Using Graywater	State	% Using
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
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

[a]The NPD Group, 1999. The association conducted a Graywater Awareness and Reuse Study based on screener data. Number of respondents answering screener = 61,377; number of graywater reusers = 2416. NA = data unavailable.

APPENDIX D CALCULATIONS IN SUPPORT OF FIGURE 2

Statistic	2000	2030 (est.)
No. of US Households	117,306,811	144,210,039
No. of California Households	12,736,312	16,182,878
% of US Households Using Graywater	7.0%	10%
% of California Households Using Graywater	13.9%	25%
No. of US Households Using Graywater	8,211,477	14,421,004
No. of 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

Statistic	Value for Statistic	Source of Data or Projection
Population of US, 2008 (est.)	303,824,640	CIA World Factbook, 2010[11]
Population of US, 2030 (est.)	373,504,000	US Census Bureau[12]
No. of members per household, US, 2000	2.59	US Census Bureau[13]
% of households with graywater systems, US, 1999	7.0%	Soap and Detergent Association[14]
Population of California, 2007	36,553,215	US Census Bureau[15]
Population of California, 2030	46,444,861	US Census Bureau[16]
No. of members per household, CA, 2000	2.87	US Census Bureau[17]
% of households with graywater systems, CA, 1999	13.9%	Soap and Detergent Association[18]

[a]Adapted and modified from California Graywater Policy Center, 2009.

[11]CIA Factbook, 2010.
[12]US Population Projections, 2008.
[13]California Quick Facts, 2009.
[14]Fate - SDA Science, 2010.
[15]California Quick Facts, 2009.
[16]Population Projections – State..., 2008.
[17]California Quick Facts, 2009.
[18a]The NPD Group, 1999, p. 14.

APPENDIX E SUMMARY OF STATES' GRAYWATER REGULATIONS

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

State	Agency	Title/Chapter	Do Rules apply to Residential?	Flow Limits	Do Rules Apply to Commercial?
Alabama	Alabama Department of Public Health, Environmental Services	Onsite Sewage Disposal Subdivision	Yes	N/A	Yes
Arizona	Arizona Department of Environmental Quality	R18-9-701 ADEQ Administration Code	Yes	N/A	Yes
Arkansas	Arkansas Department of Health Sanitary Division	Alternate Systems Manual	Yes	N/A	Yes
California	California Building Standards Commission	California Plumbing Code (Title 24, Part 5, Chapter 16A)	Yes	250 gdp	No
Colorado	Colorado Department of Public Health and Environment	Guidelines on Individual Sewage Disposal Systems	Yes	N/A	Yes
Connecticut	Connecticut Department of Public Health	Public Health Code Regulations & Technical Standards	Yes	N/A	Yes
Florida	Florida Department of Health Bureau of Onsite Sewage Programs	Public Health Chapter 381.0065; Florida Administrative Code 64E-6	Yes	75	Yes
Georgia	Georgia Department of Human Resources, Division of Public Health	Department of Human Resources Ch 290-5-26	Yes	>500	Yes
Hawaii	Hawaii Department of Health, Wastewater Branch	TITLE 11 Department of Health - Chapter 62 Wastewater Systems	Yes	150	Yes
Idaho	Idaho Division of Environmental Quality	IDAPA 16.01.03 Rules for Individual/Subsurface Sewage Disposal Systems	Yes	N/A	No
Kentucky	Kentucky Department of Public Health, Protection and Safety Division	902 KY Administrative Regulations 10:085	No	N/A	No
Maine	Maine Department of Human Services, Bureau of Health, Division of Health Engineering	1509.0 Separated Laundry Disposal Systems	Yes	N/A	No
Maryland	Maryland Department of the Environment, Water management Administration	Innovative and Alternative Program	No	N/A	No
Massachusett	Massachusetts Department of Environmental Protection	310 CMR 15.000, Title 5: Innovative and Alternative Systems	Yes	10000	No
Michigan	Michigan Department to f Environmental Quality, Health and Water	Act 421 P.A., Acceptable Alternative Graywater Systems	Yes	N/A	Yes
Minnesota	Minnesota Pollution Control Agency/Water Quality	Chapter 7080.9010 Alternative/Experimental Systems	Yes	1000	Yes
Montana	Department of Environmental Quality	DEQ 4	No	N/A	No

APPENDIX E SUMMARY OF STATES' GRAYWATER REGULATIONS

(Continued)

State	Agency	Title/Chapter	Do Rules apply to	Flow Limits	Do Rules Apply to
Nevada	Department of Human Resources	R129-98 Sewage Disposal Administrative code	Yes	N/A	Yes
New Jersey	Department of Environmental Protection	N.J. Administrative Code 7:9A	Yes	75 % of black-water	Yes
New Mexico	Environment Department	House Bill 114	Yes	250	No
New York	Department of Health	10NYCRR Appendix 75-A	Yes	75	No
North Dakota	ND Department of Health, Environmental Health Division	Ch. 62.03-16-01 individual sewage treatment	Yes	N/A	Yes
Oregon	Department of Environmental Quality, Water Quality Division	OR administrative rules ch918 division 790	Yes	N/A	Yes
Pennsylvania	Department of Environmental Protection, Bureau of Water Quality	Title 25 Environmental protection Ch.73	Yes	N/A	Yes
Rhode Island	Department 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	Yes	Minim. of 25 gpd/pers on	Yes
Texas	Texas Commission on Environmental Quality	Existing rules under 30 TAC, Ch. 285, Subchapter H. Currently working on a set of rules to fulfill HB 2661	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	No	N/A	No