Graywater – The Black & White on Consumption and Residential Adaptive Re-Use

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The purpose of this paper is to provide a broad platform from which to examine the panacea of information regarding graywater. Rather than recommend a specific path, or narrowly define a detailed product, the intent of the information is to educate the reader on the wide range of factors that contribute to the arena of graywater including domestic water re-use, historic data, psychological motivation, municipal interpretations, current water climate, sample system schematics, environmental impact and the condition of recent trends in water greywater utilization.

Opinions and findings of fact are not intended to be used as an endorsement for a specific design or product; nor are they intended to invalidate or discredit systems, laws or ordinances. Put simply, the point is to foster general understanding of residential graywater and to provide a resource for the reader or researcher from which to form, broaden and arrive at personal conclusions. Within the body of data there exist multiple opinions as well as spellings. The spelling of greywater varies from publication to publication and is exhibited in this paper in its most commonly accepted form as "greywater" which is used synonymously to refer to all spelling adaptations. The selection of opinions and data herein are based on most current information available and were also considered by source, motivation and merit before inclusion.

Water, Water Everywhere:

The definition of Graywater varies depending on the municipality or authored paper. Graywater is most typically expressed as untreated waste water that excludes water from the toilet, kitchen sink or dishwasher. In contrast to potable water (water suitable for drinking), the expanded definition of graywater includes water from bathroom sinks, showers, tubs, clothing washers and air conditioning condensation but specifically excludes uses as consumption, and in some definitions, human consumption or contact. There will likely still be trace amounts organic compounds released by graywater but the concentrations are typically minute and this water will contain trace nutrients that the soil's upper aerobic layers and decompose and deactivate. (7)

Black water, in contrast to graywater, is considered contaminated and requires treatment before it can be released into the water supply. Black water, commonly referred to as sewage, originates from toilets, kitchen sinks or any other source of coliform bacterial waste. Historically, pathogens in this type of untreated water were the source of widespread disease in developing cities in the early to late 1800's and were widely blamed for multiple epidemics such as the Cholera epidemic of 1854 that decimated over 5% of Chicago's population. These epidemics also included typhoid and dysentery, also a source of pollution from inadequately treated sewage. (8)

Historically, black water has left a black mark in many early populated areas and continues to be a threat to human health. As a result, all cities and more developed countries came up with control systems for large scale black water treatment that keep the effluent away from sources of public drinking water. According to the United States EPA, most municipalities operate one of 2 basic types of sewage systems, a Combined Sewer System (CSS) or a Sanitary Sewer System or SSS. The CSS, a much older model, combines both rainwater runoff from street or 'storm sewers' and incorporates it with sewage from individual homes and businesses. All effluent from the CSS collects it all at a treatment plant. This more antiquated system, in use even to this day, has serious drawbacks that include the inability to treat large amounts of sewer water during torrential rainfall. When the CSS is overrun with rainwater or flooding, the untreated water and rainwater mix are typically released into public water ways, canals, rivers and lakes. In contrast, the SSS is a sewer system only and does not incorporate street runoff or rainwater from storm sewers. The volume of water, in contrast, is more easily controlled. Also, the saturation of wastewater and waterborne coliform bacteria is typically higher, requiring less energy to process a smaller amount. The CSS system, still found in 772 older cities in the northeastern United States continues to pose environmental threats [Figure 1]. Cities of Chicago and New York still employ the CSS system to varying degrees and continue to struggle with natural rainwater events that require pollution of neighboring water ways.(8) Newer cities and new infrastructures are typically of the SSS design but still face challenges related to growing infrastructure volume. In any case, graywater can be a source of relief to control cost, growth, and sustainability of this infrastructure.

[Figure 1] Locations of CSS cities and towns across the United States

The Debated Solution:

Views on graywater re-use at the domestic level are currently a mixed bag. Arguments for and against abound. Municipalities that have not investigated this source of water savings or have restricted it from commercial and/or domestic use often site concerns about soil contamination, municipal sanitary sewer operation, odors, and other public nuisances. While some inductive logic accepts that reduced water flow to treatment plants not only reduces municipal water treatment costs as well as the growth of infrastructure, opponents have countered, arguing that lack of water flowing through municipal systems may cause further backup of the system from settlement of solids.

To date, there is no available data to support the theory that graywater use will negatively impact a specific sewer system. In all, however, the extent to which graywater use in California is estimated to reduce actual flow rates are a maximum of 4% which is considered insignificant (9). The concern of reduced flow lands squarely on dissolved solids, and the lack of flow to re-incorporate these solids and prevent obstruction. Even in the highest use areas, such as Arizona (13% graywater systems), no significant impact has been reported.

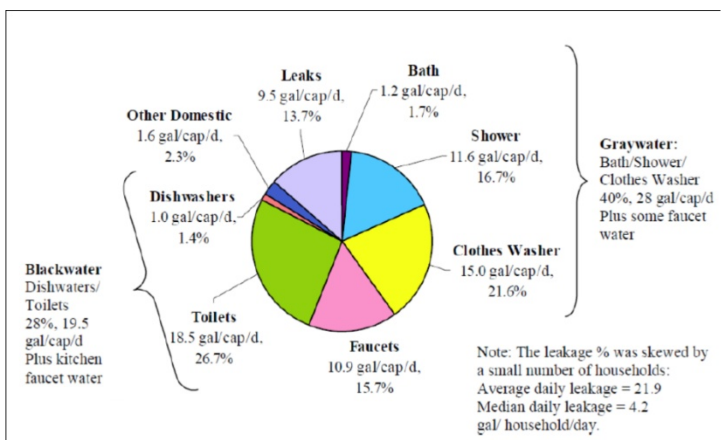
Research has yielded numbers that estimate a range of 40-80% of the water used domestically can be classified and re-used as graywater. Stronger evidence from the overlap of research suggests that the mean number lands nearer to 50%. Even with the most favorable of findings, further hurdles have historically inhibited the use and approval of graywater systems at the residential level.

Consumption – A Growing Problem:

History may still be our teacher. Before widespread availability of piped water and sewer systems, graywater reuse was quite common. Even at the turn of the 20th century, reuse of water for washing and bathing were common practice. This water was placed on plants compost piles or in the garden. Little was used and little was wasted. Graywater reuse is a 'discovery of an 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 tap water and easy waste water disposal.'(8)

The problem of water consumption and the growing demands of our ever expanding infrastructure is nothing new. The fact is, over the past 100 years, the culprit for our rampant use is piped water and the sheer availability of potable water. Compared to rural America in 1910, the each person used an average of 10 gallons of water per day but, with the advent of pumped municipal water, that number grew to 60 gallons per day by 1955. (6) With the availability of water using appliances, larger homes, sprinkler systems, and private swimming pools, by the end of the 20th century the average American was using over 100 gallons of clean drinking water per day. [Figure 2] Currently, we flush about 5.7 billion gallons of water per day down the toilet. (6) The remainder of this drinking water is used to wash cars, water ever hungrier lawns, wash our clothes and dishes.

Today, many dryer states and countries, such as Arizona and Australia, have embraced the fact that precious drinking water is to be cherished and used sparingly. These municipalities have addressed water conservation by embracing and implementation of multiple programs to curb growing water use and recycle water. In our own state of Texas, the ability to water lawns and crops is highly limited and continues to put



[Figure 2] Average indoor residential water usage for 12 North American cities (Residential End Uses of Water, Copyright ©1999 American Water Works Association and AwwaRF, (AWWA 1999)) more of a strain on our environment. There is simply not enough potable drinking water to go around. Charles Fisherman, author of the *Big Thirst* said it best:

> *"The golden age of water is rapidly coming to an end. Right now, 40 percent of the world's 6.9 billion people don't have easy access to clean water. By 2050, there will be 2.4billion more people on the planet. They will be thirsty."*

Turning up the heat:

Fast forward to 2011, we are in the middle of a record-breaking heat wave and drought in the Midwest United States and the driest 7 months in over a century in Texas. Some of the historically more lush parts of Texas, such as Houston have now received less annual rain than some parts of the Sahara Desert. Texas, however, is not alone. Within the United States, record breaking temperatures are also accompanied by record dryness. Boise City, for example, has gone for 277 days with no more than one quarter of one inch in a single day. (1) The strength of La Nina, the likely culprit, is projected to remain strong and lengthen this record. (2) The result of these disastrous conditions has left the these geographic areas with failed crops, wildfires, dying trees, watering restrictions, depletion of reservoirs and reduced flow rates at local springs that have flowed for centuries. At the same time, the infrastructure of these locations continues to grow; one of the fastest in the country is Austin, Texas. In the Austin area alone, Lake Travis, a major water source is over 40' from full and is now so low that original structures that have been covered for over half a century are again visible.(3) With a strained aquifer and surface water supply the ongoing water restrictions have no end in sight and the results of this have precipitated heavily on all of Texas.

The results are staggering. In a typical drought, the loss of smaller plants and grasses is expected but in this case, we are seeing large historic trees as well as the probability of a highly developed canopy of millions of trees dead in one season. (4) In addition to the loss of vegetation is the loss of capital investment in personal property. Foundation failures at the residential level are putting foundation companies on overtime with a geometric rise in orders for foundation repair. (5) Drought alone has, in the past, set the stage for change and implementation of adaptive re-use of water, but there is likely more at work that can produce a change of habit.

Motivating Factors:

At the individual level, there are several factors that encourage exploration of graywater reuse. Watering restrictions and subsequent fines are typically, the result of droughts, are in direct conflict with the homeowner's objectives. Primarily this begins with the homeowner and the need to preserve property value as well as control their environment. Control over cost of water is a strong driver while cost of wastewater, often broken out as a separate line item, may also be reduced. While the rate charged for water is not a control factor, the amounts used as well as any financial incentives that a municipality offers can and do provide incentive. Homes with a septic system will also increase the life and capacity of home sewage treatment by separation of black and graywater. There is also the environmental approach, a more altruistic "save the planet" desire to reuse graywater. Ultimately, however, the use of a well planned graywater system will likely offer value through more control over their investment as well as control over the total amount of water used. Finally, of all motivating factors, the more industrious property owner will encounter internet discussion, offers of gray-water planning at hardware stores, and, essentially more publicity about do-it-yourself graywater systems which can, alone, stir the pot enough to motivate some type of installation.

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.

[Figure 3] Graywater reuse across the United States based on 1999 Data from the NPD Group and 61,377 respondents.

Motivation can also be found from actual municipalities. Arizona, the most arid state in the union, not only allows graywater but provides education resources and financial incentives to retrofit or install systems in new construction and existing construction. The city of Tucson, for *example*, offers guides on how to implement graywater systems and provides instructional videos, workshops, tax credits and lowered waste water billing programs. (8) The result is a state with 13% domestic graywater use in 2011, one of the top in the nation compared to use in 1999 which was only 3.6%. [Figure 3] In 1994, California was the first state to implement graywater standards to its code with and had an estimated 13.9% domestic graywater re-use. Other large states such as Texas (11% graywater reuse) and Florida (6.1% domestic graywater re-use) (9) each have graywater legislation, albeit with a vastly differing language and specificity on handling.

The Graywater System:

As mentioned earlier, droughts typically bring on a host of interest in water control systems, commonly as a result of water rationing, municipal incentives, environmental consciousness, and other factors which lead to making an investment in a graywater system. These systems take on a wide range of complexity, and cost while municipal restrictions and incentives vary widely from state to state, at the city, county and sometimes residential HOA or POA levels.

Considerations for implementing the most simple of systems usually center on cost versus return on investment. The least expensive typically focus on re-use of laundry water only. This approach is not only the most common but also protected in some states and municipalities such as Travis county, Texas, where these systems can be grandfathered in. From simple re-use of washing machine effluent to more robust whole house systems, the cost can range from a few hundred dollars to fully automated systems that run close to $10,000. To meet basic codes below, however, it is estimated that an investment of $1,000 to $3,000 will yield a system acceptable to most municipalities that allow and inspect graywater systems. [Figure 4] These requirements typically involve the following:

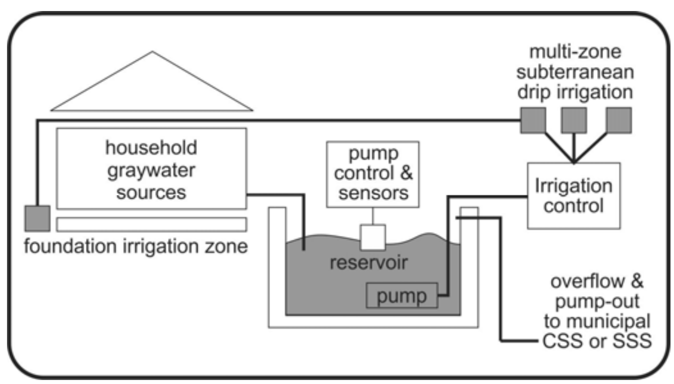
1) Origination of graywater from acceptable sources
2) Collection reservoirs of not more than 400 gallons per household (but typically a 50-gallon storage device suffices)
3) Methods of keeping the water from human, insect and animal surface contact (with exception where graywater is allowed for flushing the toilet)
4) System to pump, reuse, or distribute the water for approved uses (typically flowerbed irrigation but not including gardens with edible plants)
5) System to evacuate collected water over 72 hours old to CSS or SSS.
6) Elimination of surface pooling of water from distribution or irrigation devices.

More elaborate systems include:

1) Chemical or UV treatment of water.
2) Enlarged collection systems that allow for longer hold times and extended reuse applications.
3) Monitoring systems to switch between municipal water supply and graywater supply for sprinkler systems including backflow prevention.
4) Color coded piping (typically purple) for all graywater systems.
5) Separate quantity metering for municipal requirements and discount credits
6) Integration with a landscape irrigation controller and foundation watering systems.

While retrofitting existing homes to collect graywater from all acceptable sources will likely prohibit many from taking complete advantage of the full potential of water reuse, it is new construction that will likely be the key moving forward.

Tucson, Arizona requires that all homes built include a collection system that complies with UPC and also allows for the connection to a future system since September of 2008. (8) The cost for creating a dual collection system via drainage plumbing in new construction is relatively inexpensive and offers the homeowner the ability to maximize this investment more immediately and at lower entry cost.



[Figure 4] Schematic layout of typical domestic graywater components, courtesy Structural Environments ©2011

Trickling Forward:

Future potable water availability is generally expected to worsen in all world geographic locations. Coupled with the fact that our current use model is not sustainable when considering the prospect of worsening droughts, continuing urban sprawl and current economic forecasts, and population growth, it is likely that water re-use at all levels will become more seductive to those who govern and budget as well as to those who consume.

The trend for proactive and permissive change has already begun in several states such as California, Arizona, and Florida but legislation and research is lagging behind in many other states and municipalities. Agencies leading the forefront for change and sustainable adaptive reuse is the USGBC (United States Green Building Council) and its implementation of the LEED program. This internationally recognized building program has set the standard not only in sensitivity to water issues but also sustainable design and construction techniques. Other organizations which set code standards have also made provisions for water re-use including UPC (used by the City of Austin in Texas) and the IAPMO which promulgates IPC or International Plumbing Code. Between the codes, discrepancies on handling and labeling different types of re-used waters are often desperate and either contradict or differ from how local municipalities govern graywater. Nevertheless, efforts to more uniformly coordinate standards are already underway.

Closing Remarks:

Managing our most precious resource in the future will require a multi-faceted approach. Inclusion of all water saving technologies, better use habits, and re-use are all part of a much larger picture for sustainable water use. At the present moment, considering the facts, the United States has only just begun to deal with graywater and address the mechanics by which we can move forward more collectively. The general lack of research connected with graywater systems, their impact on municipal systems coupled with lax, non-existent or completely unreceptive local governing guidelines, incongruent national codes, and lack of education on appropriate systems has already given rise to a discord of aberrant local code that conflict with and contradict newer attempts to coordinate a united front. Thanks to the recent efforts and structuring by such entities as the American Water Works Association and the WateReuse Association, structuring a universal governing code is currently in the throes of development that will hopefully provide adoption of common guidelines across communities and pave the way for logical and safe reuse practices.

Today, we are concerned with how our new homes save electricity, how to cheaply cool and heat the air, how to improve indoor air quality (lower VOC's), how to stop the gain or loss of heat and even how to limit water use. It is likely that these approaches alone will not be enough. Implementation of graywater systems in new residential construction is a proven and affordable approach to furthering reuse of our water supply and saving municipal dollars. Creating homes that are pre-plumbed for elegant and efficient placement of this resource is not only possible, but attractive from many perspectives. Just as we strive to save other resources, our built environment can also incorporate pre-plumbing for water savings and re-use. The questions to ask ourselves and our legislators are now more pressing than ever: Why are graywater systems not mandated in new residential and commercial construction in my community; What would we save in terms of potable water, infrastructure and monetarily (both individually and as a community) to implement standards and incentives to save and reuse domestic water; What new legislation is necessary to effect meaningful change in your municipality; When you turn on the faucet, flush the toilet, or take a shower, where does this water come from, and, more importantly, where does it go? ▪

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