ITEM NO. 31

Executive Summary

Residential Greywater Irrigation Systems in California:

An Evaluation of Soil and Water Quality, User Satisfaction, and Installation Costs

Greywater Action

in collaboration with

City of Santa Rosa and Ecology Action of Santa Cruz

Residential Greywater Irrigation Systems in California: An Evaluation of Soil and Water Quality, User Satisfaction, and Installation Costs

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All errors are our own.

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Residential Greywater Study

As water shortages become increasingly common, new and innovative ways to conserve and reuse water are critically important. Widespread reuse of household greywater, which is discharge water from sinks, washing machines, showers and baths, has many potential benefits; it can reduce overall potable water consumption, thus decreasing the demand for surface and groundwater. Greywater use can reduce energy consumption, as it offsets the need to treat water to potable quality for irrigation, and can improve water quality by reducing flows to over-loaded septic systems.

Lack of scientific data on how greywater affects soils and plants has been a barrier for widespread implementation of greywater systems for residents and public agencies alike. Lack of data regarding the costs of installation, permitting and maintenance for greywater systems also present barriers for households that are considering greywater reuse. We seek to collect this data through a multifaceted study of residential greywater systems in Central California.

The study:

We studied 83 greywater systems in 66 homes in the San Francisco Bay area, Monterey Bay area and the Santa Rosa area , and:

- Conducted a one-hour structured interview at each households. Questions elicited demographic information, details about the greywater system(s) and other water conservation practices (e.g rainwater harvesting), laundry and soap products used, and irrigation methods and frequencies
- Collected a greywater sample from each system and tested it at a laboratory for pH, salts (EC, TDS), and boron levels.
- Visually examined 127 plants irrigated with greywater and recorded qualitative plant health metrics for each. We briefly observed more than 1,000 plants irrigated with greywater at the study sites. We looked for leaf chlorosis, leaf necrosis, insect presence, diseases (e.g. mildews, leaf curl, etc.) and abnormal growth.
- Conducted a separate survey of 20 professional greywater installers from San Francisco Bay area, Monterrey Bay area, Santa Rosa area and Los Angeles area (landscape and plumbing contractors) about material costs, labor, and permitting costs for 259 systems they had installed since 2009.
- Collected two soil samples, one from soil under greywater outlet, the other from an area of the yard unaffected by greywater and tested it at a laboratory for pH, salts, and boron levels. To test for an effect of greywater irrigation on the soil we analyzed the difference between the soil samples at each site.

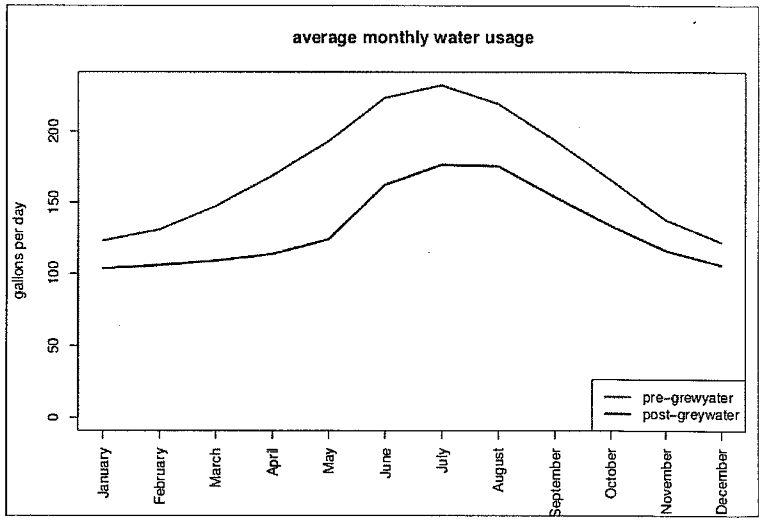
We found:

Overall, the greywater systems in our study saved water and had few problems. Other key finding include:

- Per capita water consumption decreased by an average of 17 gallons per day after greywater system installation, at least half of which is directly attributable to water savings from greywater reuse. This translates to each household saving an average of 14,565 gallons each year after installation of the system. Average annual savings varied by season, with higher savings in spring and summer, (nearly 10,000 gallons), and lower in fall and winter, (close to 5,000 gallons).

99% of people were "very satisfied" or "satisfied" with their system

- Greywater did not negatively affect soil or plant health.
- Quality of greywater was typically suitable for long-term irrigation of plants, so long as households used products without sodium or boron compounds.
- System users were overwhelmingly satisfied with their systems.
- Though people did very little maintenance on their system, no major problems developed. However, more education and a few changes in design can improve performance of greywater systems and avoid potential problems.



We learned:

1) The importance of user education.

- A large number of our respondents did not maintain their greywater systems. This leads us to conclude that greywater promoters, educators and installers should do more to educate people about how to maintain their systems, and installers should create maintenance contracts with their clients.
- Furthermore, we believe that a strong emphasis on good choice of soaps, detergents, and cleaning products is important for higher quality irrigation water from greywater systems. Most people in our study group used products with little or no salts or boron, resulting in better quality irrigation water. The few greywater samples that were not safe for irrigation came from households that used either powdered detergents, known to be high in salts, or brands not typically considered "greywater friendly" nor listed all ingredients.

2) Agencies or organizations promoting greywater should consider:

- Promoting laundry-to-landscape and branched drain systems, as these types of systems are more economical, have few problems and high user satisfaction.
- Education programs should also include support for implementation, since most people installed their systems within a year of learning about greywater. For example, installation workshops, subsidized installations, or referrals to local installers could enable people to follow through with their ideas for a home greywater systems.
- Use of plant-friendly products (without salt and boron) should be emphasized, to ensure good quality greywater for irrigation.

3) Greywater can be of good quality for irrigation water. The quality of greywater for irrigation in our study was better quality than other studies have found.[2]

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Al-Hamaidedeh and Bino, 2010; Alifya, et al., 2012; Misra et al., 2010 (Full reference in report)

- We believe this difference is due to the fact that most of the households in our study changed their products after installing greywater system, or were already using plant friendly soaps and detergents prior to irrigation with greywater.

4) Greywater systems save water. Overall water usage decreased after households installed greywater systems by an average of 17 gallons per capita per day (gpcd), which represents an average reduction of 26% (48 gpcd down from 65 gpcd).

5) Greywater systems have a potential to create quality green jobs, though under current California water rates ($3-6 per hundred cubic foot), professional installations have a payback time greater than 20 years, potentially longer than the homeowner owns the home.

- The payback period calculation doesn't include other potential benefits of the greywater system that are more difficult to quantify, such as "drought insurance" for landscapes during water restrictions, extending the life of septic systems, delaying the need to drill deeper wells, time savings on watering, or increasing a home's resale value.
- To overcome financial barriers, incentive programs, rebates and public agency sponsored workshops can help lower costs, while increasing conservation water rates and peer-to-peer sharing of greywater system satisfaction will help drive market demand for greywater irrigation systems in the future.

6) Design improvements:

- We observed a few minor problems that could be avoided by better design or more frequent maintenance. A few sites had pooling or runoff of greywater, and a few others experienced uneven distribution of greywater to plants. Locating greywater outlets away from pathways can prevent any pooling that results from lack of maintenance or other causes, and reduce risk of exposure to the public. In systems where greywater outlets are located near hardscape, such as the cement paths of the two sites with runoff in our study, three simple design changes would have prevented runoff and subsequent potential for public exposure 1) Ensure sufficiently large basin sizes. 2) Move the basin farther from the path. or 3) Create a mound of soil (a "berm") next to the path to prevent greywater from overflowing onto the path.

- Overwatering is another potential problem related to system design. We observed two system designs resulting in extreme over-irrigation.

- Overall, 95% of plants observed in the study grew healthily with greywater with no obvious changes from when they received freshwater irrigation. Several sites reported plants that had been unhealthy becoming healthy after greywater irrigation. One bougainvillea vine didn't flower much until it received greywater, a fig tree began to "thrive", and a lime tree that the homeowner thought was going to die began to flower and produce fruit.

7) Many different plants can be successfully irrigation with greywater. We saw 127 plants from 68 different species including:

- Fruit trees (almond, apple, apricot,

Health of Greywater Irrigated Plants

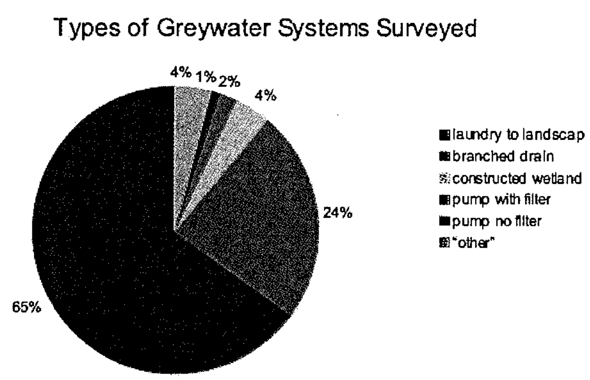
	No signs	Some signs	Severe signs
Leaf necrosis	95%	5%	0%
Leaf chlorosis	94%	5%	1%
	Fully healthy	Mostly healthy	Unhealthy[1]
Overall health	95%	2%	3%

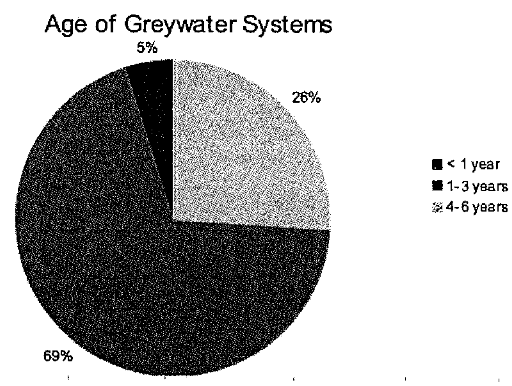
1- Of the unhealthy plants, half were identified to be unhealthy before greywater irrigation began.

Asian pear, avocado, cherry, fig, lemon, lime, mandarin, olive, orange, peach, pear, persimmon, pineapple guava, plum, pluot, pomegranate)
- Edibles (artichoke, arugula, blue berry, chard, grape, kiwi, herbs, raspberry, sugar snap pea)
- Ornamentals (bamboo, bougainvillea, willow, box wood, buddah's hand, butterfly bush, many flower species, camellia, maples, red oak, silverberry, spice bush, umbrella tree)
- CA natives (ceanothus, flowering currant, mimulus, rushes, salvias)

In conclusion, greywater is an important component of reducing total residential water demand. These systems can work synergistically with other water conservation strategies, such as lawn removal, conversion of non-greywater irrigated landscapes to xeriscaping or native plantings, rainwater harvesting and rain gardens, and installation of water-efficient fixtures and appliances. In preparation for water shortages and reduced water withdrawals to help restore our aquatic ecosystems, water districts could encourage deep savings by promoting a suite of options to reduce demand with increasing incentives to the homeowner as they incorporate all the conservation strategies.

Sample of charts in report:





User Satisfaction with Greywater System					
	% Very satisfied	% Satisfied	% Neutral	% Dissatisfied	% Very dissatisfied
Overall satisfaction	75	24	1	0	0
Reliability (need for maintenance)	69	23	7	1	0
Irrigation performance	55	40	5	0	0

Greywater and Non-greywater Irrigated Soil Testing Results

		Median	Min	Max	Samples in **"generally safe"** range	Samples in **"slight to medium"** risk range	Samples in **"severe"** risk range	median difference btw. GW and non-GW samples
Soluble salts (mmhos/cm) or dS/m	greywater	0.17	0.05	2.6	97%	3%	0%	0.01
	non-GW	0.16	0.05	1.85	100%	0%	0%	
pH	greywater	6.5	5.3	7.5				
	non-GW	6.5	5.2	7.6				-0.1
Boron (ppm)	greywater	1	0.2	9.3	55%	42%	3%	
	non-GW	0.8	0.2	19.3	65%	32%	3%	0

Greywater Testing Results

		Median	Min	Max	Samples in **"generally safe"** range	Samples in **"slight to medium"** risk range	Samples in **"severe"** risk range
EC (mmhos/cm)	greywater	0.31	0.07	4.82	85%	14%[2]	1%
	municipal water[1]	0.38	0.04	1.64			
TDS (ppm)	greywater	193	47	3133	84%	15%[2]	1%
	municipal water[1]	240	29	846			
SAR[3]	greywater	1.8	0.35	64	80%	18%[2]	2%
	municipal water[1]	no data available					
pH	greywater	6.5	5.5	9.7			
	municipal water[1]	8.3	6.7	9.7			
Boron (ppm)	greywater	0.04	0.003	4.55	92%	5%[2]	3%
	municipal water[1]	0.31	ND	0.88			
Chlorine (ppm)	greywater	24	4	210	94%	6%[2]	0%
	municipal water[1]	24	3	394			
Sodium (ppm)	greywater	32	7	1024	85%	13%[2]	2%
	municipal water[1]	23	3	140			

1- We averaged the quality of municipal water for the seven water districts of the study area. Since there was not an even distribution of sites in each water district, the averages show above do not reflect an accurate estimate of constituents preexisting in the water, rather they shows levels that can be found in municipal water.

2- Most samples were at the low end of range, see results section for details

3- SAR- We used the adjusted Rna calculation

For full report go to: www.greywateraction.org