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Monitoring Graywater Use: Three Case Studies in California

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Background

The California Department of Water Resources (DWR) with the City of Santa Barbara and East Bay Municipal Utilities District initiated the Graywater Study in the spring of 1996. Graywater is untreated waste water which has not come into contact with toilet waste. The purpose of the study was to collect data at single-family sites to determine the benefits, costs, and impacts of graywater. The project was modeled after the 1992 City of Los Angeles Office of Reclamation's Graywater Pilot Project. It was hoped that there would be ten sites throughout the State to participate in this two-year project. While initial interest was great, only three sites in the cities of Santa Barbara, Danville (Contra Costa County), and Castro Valley (Alameda County) were able to obtain local permits and meet the other requirements of the study.

Because of the limited number of sites, this should not be considered a comprehensive, definitive report on graywater, either extolling or discouraging its use. Rather, it is a valuable case study with observations of the operation of these three legal graywater systems over a two-year period.

Soil and Water Quality Results

Sampling and Testing Procedures

DWR provided specific sampling procedures and basic instructions to the participating agencies. Soil samples were taken from within six inches of the sub-surface irrigation line. An Oakfield stainless steel tube was used to take several soil cores to seven inches deep, discarding the top one inch. The soil cores, constituting of at least 500 grams of soil, were deposited into a ziploc plastic bag.

Water samples were taken from an outlet of the surge tank and deposited directly into a sampling tube, then poured into a one-quart polyethylene container.

Samples were labeled; packed in a cooler and iced to maintain the temperature at 4 degrees Celsius for 25 hours; and sent in overnight delivery to the DWR laboratory in West Sacramento.

The water samples were analyzed immediately upon receipt at the lab. The soil samples were dried, then weighed out to 50 grams of soil. Then 500 milliliters of de-ionized water was added to the soil, and extracted after 48 hours. Finally, the water was filtered from the soil and analyzed.

The soil and water samples were tested for Boron, pH, Sodium, Chloride, Calcium, Magnesium, Specific Conductivity, and calculated Sodium Adsorption Ratio. These chemical parameters indicate conditions of the soil that may affect plant growth directly or indirectly.

Laboratory Results and Observations

The chemical composition of graywater varies greatly based on numerous factors including the original quality of the water coming to the home; personal habits of the family members; which plumbing fixtures are connected to the system; and usually most importantly, the laundry soaps used. While samples taken from the graywater tank provide important reference data, samples from the soil are better indicators of the potential effect on the soil and plants. Therefore, the following observations are based primarily on the soil-based samples.

See Table A for a complete tabulation of the laboratory reports. The laboratory reports were reviewed in terms of ranges of values of chemical parameters for plant growth conditions; upward trends over the two-year period; and obvious spikes of chemical concentrations. There were no significant, consistent upward trends or spikes in chemical concentrations from the soil samples in any of the constituents tested. However, at the Castro Valley site, there was a temporary increase in salinity in both the graywater storage tank and the soil from July 1996 until the end of 1996 (see Specific Conductance, SC.) The value of 1060 micromhos/cm indicates that salt had accumulated in the soil to a potentially lethal level for plants. Presumably, either supplemental irrigation with potable water or rainfall between November 1996 and April 1997 leached the salts from the soils.

pH (acidity/alkalinity)

The normal range for pH is from 6.5 to 8.4. Measurement of pH of less than 7 indicates an acidic soil; 7 is neutral; and greater than 7 indicates an alkaline soil. Sodium, Potassium, and Calcium are alkaline chemicals. Lab reports from all except one sample for all three sites showed that pH exceeded 7.1, indicating alkaline soil conditions. This supports the recommendation that gardeners avoid planting acid-loving plants such as azaleas, gardenias, camellias, and rhododendrons in landscapes irrigated with graywater.

Also, pH can be an indicator of the potential for drip irrigation emitters to clog. The combination of high pH and high Calcium can cause potential clogging problems due to a build up of precipitated lime in the emitters. According to Pestcod (FAO 47, Wastewater treatment and use for agriculture, 1992):

<u>Degree of Restriction of Use</u>

	None	Slight-Moderate	Severe
pH	<7.0	7.0-8.0	>8.0

Based on these criteria, pH was slightly to moderately problematic in terms of clogging emitters at all sites.

Hardness (Dissolved Hardness as $CaCo_3$)

The concentration of Calcium Carbonate ($CaCO_3$) is an indication of the capacity of water to precipitate soap (form a lather). For irrigation equipment purposes, soft water is preferred over hard water. The lower the concentration of $CaCO_3$, the softer the water:

Concentration of $CaCo_3$ (mg/L)	Description
0-75	soft
75-150	moderately hard
150-300	hard
300 and up	very hard

(from the Quality Criteria for Water, U.S. E.P.A., 1986)

Three of the soil samples were in the "moderately hard" range while all the rest were in the "soft " category.

Sodium (Na)

High levels of Sodium can degrade the soil's physical condition and contribute toward an alkaline soil condition. In addition, high Sodium can be toxic to certain plants and disrupt the Calcium nutrition of the plant. UNFAO (United Nations Food and Agriculture Organization Publication #29: Water Quality in Agriculture) indicates "no problems" at levels less than 69 mg/L, "increasing problems" between 69 and 207, and "severe problems" at greater than 207. Neither the Santa Barbara nor Danville sites registered Sodium readings from the soil samples that would cause problems. Castro Valley registered three readings in the "increasing problems" category, and one indicating potentially "severe problems." (Based on the soil samples being multiplied by 25 to estimate the concentration as a "saturated paste," the scientific standard by which potential plant effects are based.)

Specific Conductivity (SC)

The specific conductivity (SC) or electrical conductivity (EC) of the water is an indicator of the salinity hazard. It is a measure of all dissolved salts in the water. The higher the concentration of salts and minerals, the greater the potential for adverse impacts on the soil and plants. The standard classification of soils from the National Soil Survey Handbook, NRCS, 1993, related to salinity is:

Class	Specific Conductivity (Ece)
0. non saline	0-2,000 micromhos/cm
1. very slightly saline	2,000-4,000
2. slightly saline	4,000-8000
3. moderately saline	8,000-16,000
4. strongly saline	> 16,000

None of the samples exceeded 2,000 micromhos/cm, indicated that non saline conditions exist in all cases tested. In nearly all cases, the EC was near or below 1 dS/m, and does not pose a salinity hazard (SP/1000=dS/m, multiplied by 24 for an estimated EC.) In one case in Castro Valley, the EC increased in the tank to 1.9 dS/m, but later decreased to 0.4. Should the EC in the water increase to this level on a frequent basis or remain at this level for a prolonged period of time, certain sensitive plants could suffer salt injury.

Sodium Adsorption Ratio (SAR)

The Sodium Adsorption Ratio is an important parameter because, in combination with SC, it can indicate whether a water source will reduce the infiltration rate of water into the soil. SAR is calculated from the concentrations (in milliequivalents per liter, meq/L) of Sodium, Calcium, and Magnesium. High Sodium Adsorption Ratios reduce the infiltration rate of water into the soil. Soils with values for Sodium Adsorption Ratios of 13 or more may result in soils with reduced permeability and aeration, and a general degradation of soil structure (according to the National Soil Survey Handbook, NRCS, 1993). All SAR readings in this study were well below 13.

A look at the combined effect of SAR and EC also indicates that graywater at these three sites would not create an infiltration or permeability problem. This is based upon the following criteria from Dr. Jim Oster, Soil Specialist for the University of California Riverside Cooperative Extension:

When SAR is:	Potential infiltration problem is: Unlikely if EC is:	Likely if EC is:
0-3	>0.7	<0.3
3-6	>1.0	<0.4
6-12	>2.0	<0.5
12-20	>3.0	<1.0
20-40	>5.0	<2.0

Calcium (Ca)

In proper amounts, Calcium is an important micronutrient for plants. In excessive amounts, Calcium could clog the emitters of a sub-surface drip irrigation system, such as is often used with graywater systems, if not properly filtered. High levels of Calcium could contribute toward an alkaline soil. The measurement of Calcium levels is used to determine Sodium Adsorption Ratios, and has no established specific level of concentration that would be damaging to the soil or plants.

Magnesium (Mg)

In proper amounts, Magnesium is also an important micronutrient for plants. Likewise, in excessive amounts, Magnesium could clog the emitters of a sub-surface drip irrigation system, such as is often used with graywater systems, if not properly filtered. The measurement of Magnesium levels is used to determine Sodium Adsorption Ratios, and has no established specific level of concentration that would be damaging to the soil or plants. Magnesium levels are relatively low and are not problematic.

Chloride (Cl)

This element can cause toxicity to plants at very low concentrations. UNFAO indicates “no problems” at levels less than 142 mg/L, “increasing problems” between 142 and 355, and “severe problems” at greater than 355. Chloride measurement from the soil samples at all three sites were within the “no problem” category.

Boron (B)

This element can also cause toxicity to plants at very low concentrations. UNFAO indicates “no problems” at levels less than 0.75 mg/L, “increasing problems” between 0.75 and 2.0, and “severe problems” at greater than 2.0. All sites recorded less than 0.1 mg/L of Boron from the soil samples tested. This is well within the “no problem” range.

Conclusions

Based on the samples taken, there appear to be no problems related to hardness, SAR, Chlorine, or Boron. The pH was routinely alkaline. Specific conductivity results indicate non saline conditions. Sodium was slightly high in the Castro Valley site, highlighting what could be the greatest concern for the use of graywater: transient salinity conditions, especially in systems which use subsurface drip irrigation. Winter rains or occasional leaching of the soil would usually take care of this problem.

City of Santa Barbara's Perspective

Background

Both the City and County of Santa Barbara developed a permit system for the use of graywater during the last California drought to provide citizens a legally recognized way to use graywater to keep their landscapes alive. At that time, the City of Santa Barbara only allowed the use of graywater during a "drought emergency" condition. Many homeowners that used graywater during the drought expressed interest in using graywater after the drought was over. However, even after the State approved graywater standards in 1994, staff found problems in the process to permit and install a legal graywater system as only three permits for graywater systems had been issued by the City of Santa Barbara Building and Zoning Division since 1990. One of the City's reasons for participating in the DWR study was to develop methods for increasing graywater use with legal permitted systems.

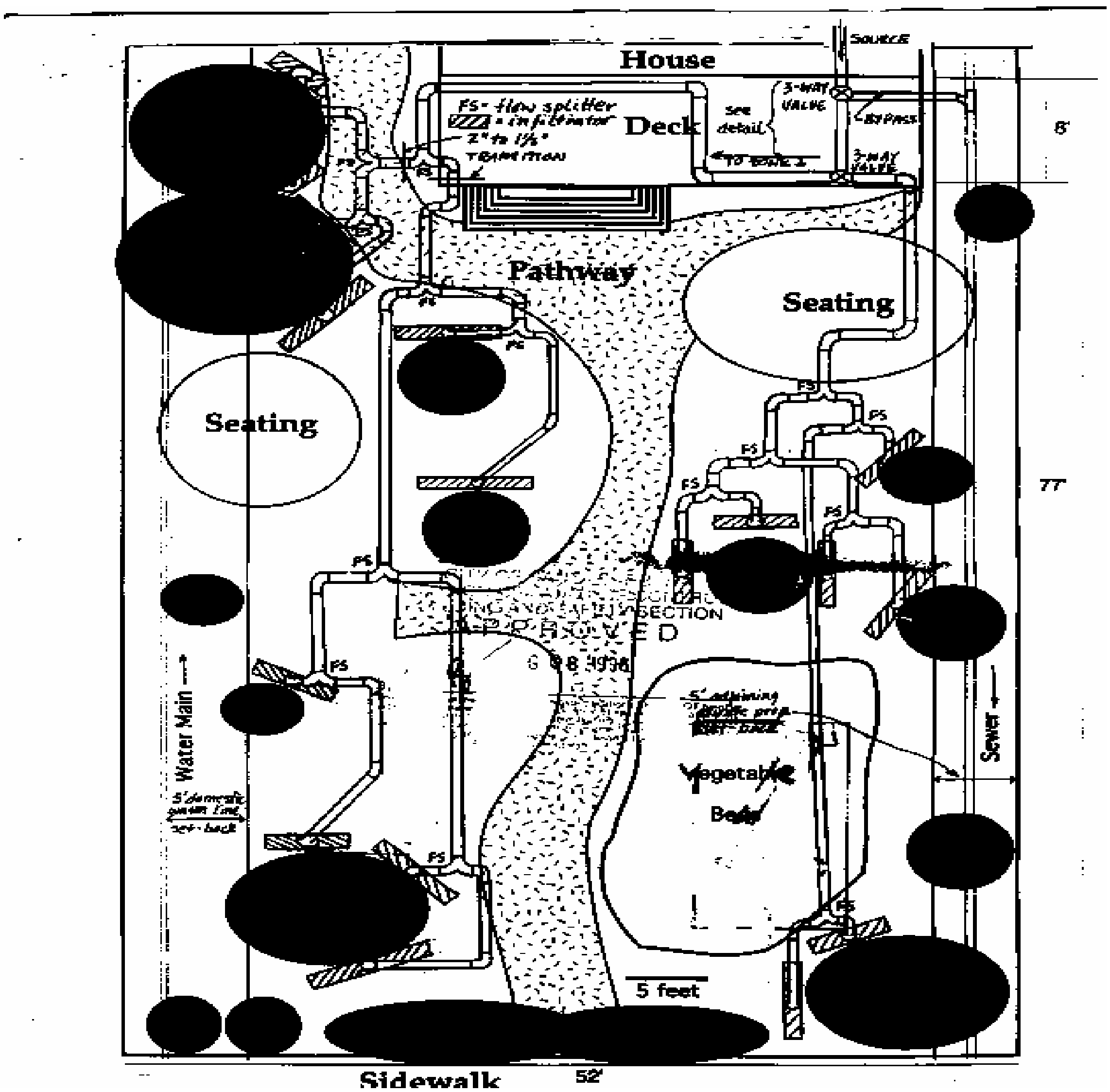
Site Characteristics

The study site is a single-family residential lot on the west side of the City of Santa Barbara. The property is 6,900 square feet with a 1,100 square foot home. The home has one bathroom. The home was torn down and rebuilt by the homeowners in 1992. The landscape consists of a vegetable garden, fruit trees, and low-water using plants. There are two large landscaped areas in the front of the house separated by a central path. Additionally there are small landscaped areas on the sides and back of the house. The homeowners are organic gardeners and therefore use only organic products on their landscaping. The landscape is heavily mulched and the soil is in excellent condition.

Description of Graywater System

Connections to the graywater system are made from the bathtub/shower, bathroom sink and clotheswasher. This is a gravity-feed system requiring no filtering and no tank. Graywater drains through 2" ABS pipe at a slope of a minimum of ¼" per one foot allowing debris to be flushed through. Infiltration is switched between two zones every 2-3 weeks to allow the soil to rest and dry out. Each zone splits the water numerous times as it flows to supply water to numerous fruit trees. Splitting is achieved through precise leveling of "T" fittings. Infiltration occurs through reservoirs consisting of buried perforated five-gallon buckets surrounded by wood chips.

The two zones are in the large landscaped area in the front of the house that irrigates a mixture of citrus, stone fruit and other fruit trees. Zone 1 is 52 square feet and irrigates six fruit trees and Zone 2 is 44 square feet and irrigates four fruit trees. See diagram below of the graywater irrigation system.



The homeowners use Oasis laundry soap (1/16 – 1/8 cup per load of laundry) in the washing machine which appears to have no negative affects on the majority of the fruit trees. Only the guava tree seemed stressed by the use of graywater. In April 1998, homeowners began using Ultra 7 enzyme cleaning solution, a soapless water treatment disk, in the laundry. They use Oasis soap periodically with the disk. Since the use of the disk, homeowners state that the guava tree appears to be doing better.

System Costs

When the homeowners rebuilt their home, they plumbed the home with the intention of installing a graywater system. Capital costs of the graywater system were low because of this foresight. The home has a raised foundation that made the plumbing changes much simpler than if the home had a slab foundation. The total materials cost of the system was $781, with $212 for the graywater system and $569 for the irrigation system. The homeowners installed the system themselves, thus reducing the labor costs substantially. The only labor costs were $350 for plumbing work. Because of the relatively basic nature of this type of system, the capital costs are significantly lower than for other types of graywater systems.

Operating costs are minimal due to the very simple, gravity system that was installed. The homeowners estimate that one hour per month is spent on maintaining the system.

Graywater Use and Potable Water Savings

Homeowners irrigate Zone 1 for 2-3 weeks and then switch to Zone 2 for the same period of time. A separate meter measures the graywater use to evaluate the potable water saved. Because the site has a gravity graywater system, it was necessary to use a meter that could operate at atmospheric pressure. A tipping bucket meter is used to measure the graywater that works by filling and tipping every 1.5 gallons and then records the tips on a digital counter. The homeowners kept a monthly log which included recording the readings of the graywater meter. The first winter the homeowners turned the graywater system off for most of January and February. From November 1996 to March 1997 the total graywater use was only 3.5 hundred cubic feet (hcf). The 1997 spring/summer graywater use (April 1997 to October 1997) was 12 hcf. From November 1996 to June 1997 there were three people living in the home, after that time there were only two people living in the home.

Graywater use for the second winter of the study was minimal. For November and December 1997 the graywater use was only 1 hcf. The graywater system was turned off for January through the end of March 1998 due to heavy rainfall. The 1998 spring/summer graywater use (April 1998 to September 1998) was 8 hcf.

Because the homeowners were continuing to landscape their property with additional plantings irrigated with potable water during the study, one cannot compare the historical potable water use of the property to calculate potable water saved. However, it is the assumption of the author that a significant percentage of the graywater used offset potable water use that otherwise would have been necessary to irrigate the fruit trees.

Benefit/Cost Analysis

Based upon an estimated life of the graywater system of 20 years, the total water savings is approximately 190,740 gallons. This is equal to 0.6 acre feet or 255 hcf. At an average cost of $3.50 per hcf in the City of Santa Barbara service area, the customer water savings is $893. Since the cost of the system was $1131, the net cost to the homeowner over 20 years would be around $238.

Since there are only two people living in the home, the amount of graywater produced was just enough for the fruit trees on the system. However, this type of system could be expanded to irrigate larger landscaped areas with more graywater at a home with an increased number of residents, which would increase the cost effectiveness of the system.

Homeowners Acceptance and Observations

Overall, the homeowners are very happy with their graywater system. The homeowners are organic farmers with a strong conservation ethic and had a positive attitude towards graywater. Installation of the gravity run system was somewhat difficult because the slope of the system had to remain at ¼" drop per 1 foot. However, once installed the simple nature of the system allowed it to be basically maintenance free.

The homeowners were pleased with the health of their fruit trees. The only problem they had was with the large amount of slugs that congregated in the reservoirs. Due to the set up of the system, fruit trees are irrigated for 2-3 weeks in Zone 1 and then graywater is switched to Zone 2. The homeowners noticed that the citrus trees appeared to do well with the continued watering for 2-3 weeks without a drying out period, however the stone fruit trees seemed to be slightly stressed by the long irrigation periods.

Experience with Regulatory Agencies

Permitting of the graywater system by the local regulatory agencies was a lengthy process mainly due to a lack of knowledge on the graywater standards. When the homeowner and the author first approached the City of Santa Barbara Building and Zoning Division (Building Division) with a request for a graywater permit, the inspectors had no knowledge of the California Graywater Standards. There was also confusion on who had jurisdiction to permit a graywater system. The Building Division referred us to the Santa Barbara County Environmental Health Department, who after having the plans for six weeks, informed us that they had no jurisdiction for review. Once this confusion was cleared up, the permit process was resumed at the Building Division and went very smoothly, as we then received the permit in three days. The cost of the permit was $80. The study site permitting process was an educational process for the regulatory agencies in Santa Barbara and they now know how to handle graywater permits.

General Observations

The type of graywater system at the City of Santa Barbara site works well for that particular size of property and the type of landscaping that is irrigated with graywater. It is a small system with low capital costs. Installing the system was simplified because this site was pre-plumbed for graywater when it was rebuilt. Homeowners completed the majority of the installation of the system themselves which reduced the labor costs substantially.

It is the author's opinion that until the permitting process with the regulatory agencies is streamlined and uniform for the State, it will deter citizens from permitting their graywater systems. Because of the confusion and lack of knowledge of the regulatory agencies, the permitting process delayed the installation of the graywater system at the study site by almost two months. A simple, straight-forward process will encourage citizens to apply for a permit.

East Bay Municipal Utility District's Perspective

Background

A mailing was sent to 500 randomly selected East Bay Municipal Utility District (EBMUD) single family customers seeking participation in the graywater study. The mailing included a qualifying survey whereby participants had to have at least four members in the family and be living in a dwelling with a raised foundation. Two sites were selected from 15 site inspections.

Site Characteristics

Both of the selected sites involved two story detached single-family dwelling with approximately 10,000 square feet of irrigated landscaping. Both sites also have four family members, three bathrooms, a clothes washer, and an automated irrigation system.

Description of Graywater System

The installed graywater systems both included the following components:

- 1/2 horsepower submersible pump
- 55 gallon surge tank
- 50 pound filter and sand
- Subsurface drip system
- Water meter
- Plumbing connections

Connections to the graywater system in both residences are made from the clothes washer, and two out of three of the bathrooms. All three bathrooms are full bathrooms, in that they contain a wash basin and either a bath or shower. The reason one bathroom at each site was not connected to the graywater system was due to cost concerns. Adding the remaining upstairs bathroom to the graywater system would have involved extensive work to get into the walls to make the plumbing changes.

At one site, the graywater irrigation system is used to irrigate a lawn area and at the other site a sloped shrub area is irrigated.

Capital, Installation and Operating Costs of System at Residence

The capital cost for each graywater system was $1250, which included the cost of plumbing connections. The labor cost for the two sites averaged $4150 each. Approximately $1,000 of the installation cost was for the installation of the irrigation system, which was required to be buried to a depth of about 9 inches in a 17 inch trench. Irrigation lines needed to be 14 inches apart and cover approximately 1200 square feet. The installation of the graywater systems was labor intensive due to the difficulty incurred in making the drain line plumbing connections from the various household fixtures. The total system capital and installation cost averaged $5400 for each site.

Landscape Quality

The quality of the landscape was reviewed monthly during the study and no noticeable negative impacts were noted. At one home, where the graywater irrigation system irrigated a lawn area, supplemental water was needed on occasion.

Graywater Use and Potable Water Savings

The estimated per capita flow from the graywater system was expected to be around 30-35 gallons per person per day or about 50% of indoor use. A water meter was installed on the graywater line running to the landscape to measure water flows from the graywater system. The average annual discharge to the landscape at one home was 74 gallons per day and was 89 gallons per day at the other home for a per capita annual average of 20.4 gallons per day. One obvious reason that the measured use was lower than expected could be due to the fact that one bathroom was not connected to the graywater drain line system in both of the homes.

Benefit/Cost Analysis

Based upon an estimated life of the graywater system of 15 years, the total water savings is about 446,200 gallons. This is equal to 1.37 acre feet or 596 hcf. At an average cost of $1.50 per hcf in the EBMUD service area the customer water savings is $895. Since the cost of the system was $5400, the net cost to the homeowner over 15 years would be around $4500. The energy cost to operate the pump was not calculated but would add to the total cost. The cost for water to back-flush the filter system (six times a year and for 10 minutes each time) over a 15 year period was calculated to be around $20.

Homeowner Responsibility/Acceptance

Homeowners were required to maintain a monthly log and note any maintenance problems or absences from the site of several days or more. Study participants were satisfied with the graywater systems and incurred no maintenance problems during the study period. Both homeowners plan to keep using the graywater system. However, they also indicated that they would not be willing to pay for these systems without a significant financial incentive.

Experience with Regulatory Agencies

The permitting and inspection process was somewhat involved at the two permitting agencies: the Town of Danville and the County of Alameda. The Town of Danville permit cost $140 and the County of Alameda permit cost $125. Neither agency was excited about permitting a graywater system. However, after several letters and several telephone calls, both agencies issued permits. Both agencies were concerned about the proper venting of the drain line system, the plumbing of an overflow return line from the surge tank to the sanitary sewer system, and the proper drain line connections. Neither agency, on the other hand, inspected the irrigation system. The County of Alameda also required that the surge tank be strapped down in case of an earthquake. Both agencies required proper labeling of the waste stream which involved a note that said "Danger- Graywater- Do Not Drink". Both agencies required a site plan showing the layout of the drain lines and the irrigation system.

General Observations/Comments

The following comments are offered based upon observations of the author made during this graywater study:

- The permitting of graywater systems can be troublesome for the permitting agency the first time around. The permitting agencies appeared most concerned about the proper venting of the graywater system.
- The drain line connection and venting costs can increase significantly when retrofitting two story homes.
- Every site has unique issues that need to be addressed for proper system installation.
- The required depth of the irrigation system makes its use impractical for many lawns and adds considerably to the expense of a contracted installation.
- It is easier to plan for the irrigation layout if the homeowner does not have an automatic irrigation system since the area to be irrigated by the graywater may not match the area irrigated by a given valve (station).
- The use of graywater did not appear to have any negative impact on the plant material.
- Graywater systems appear to require little maintenance.
- Graywater systems are more cost-effective investments for retrofitting in existing homes where the family size is large, the dwelling is single-story with a raised foundation, and where pumping is not required (sloped lot). These qualifications limit its widespread practical use.
- Graywater drain lines can be most cost-effectively installed during the construction of a dwelling. This is especially necessary for homes with slab foundations.

Soil and Water Quality Results

The graywater study concludes in November 1998. Soil and water quality analysis are forthcoming and will be presented at the Conserv '99 Conference.

Recommendations for Promoting Graywater Use

Drawing from the results of the study, the following recommendations are proposed to promote the use of graywater in California: 1. Provide the public with information on the different types of systems and their associated costs and potential benefits; 2. Improve the graywater permitting process – establish statewide guidelines that will streamline the process for a homeowner to obtain a permitted legal system; 3. Provide incentives for residences to use graywater, including dual plumbing in new construction; and 4. Encourage graywater system manufacturers to work with large hardware stores to have training on graywater systems for customers.

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