Assessment of On-Site Graywater and Combined Wastewater Treatment and Recycling Systems

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Submitted to:

U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460

August 3, 1992

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ACKNOWLEDGEMENTS

We acknowledge with deep gratitude the sponsorship of the U.S. Environmental Protection Agency and the National Association of Plumbing-Heating-Cooling Contractors Association, and the direction provided by Robert Bastian and Joanne Oxley. We also express our appreciation for the extremely valuable information and insights provided by Kenneth Krauska, John Irwin, Dr. Bahman Sheik, Allison Whitney, Art Ludwig and Larry Farwell.

Special thanks also are due to Martin Karpiscak of Office of Arid Land Studies, University of Arizona; Scott Chaplin of Rocky Mountain Institute; and the many manufacturers, distributors and plumbing contractors for their generosity in sharing information and data with us.

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SUMMARY AND CONCLUSIONS

America is facing a critical water supply shortage because of population and economic growth, persistent drought conditions, and a lack of adequate planning for future water needs. This is evidenced by current efforts in many states, as well as semi-arid and arid areas, to adopt stricter standards for water conservation. In addition, an increasing number of communities are imposing sewer moratoriums or sewer capacity restrictions.

Historically, public policy, and health codes have mandated centralized collection and treatment of all wastewater. On-site wastewater treatment and recycling systems have been allowed only in very few instances. Some of these systems involve segregation of individual waste sources into *dual piping systems* -- graywater and blackwater. *Graywater* generally is defined as used water generated by clothes washing machines, showers, bathtubs, and sinks. *Blackwater* is water that is flushed down toilets and urinals.

Many states and counties currently are reexamining their policies and codes regarding on-site wastewater treatment and recycling due to a variety of factors: persistent drought and water shortages, lack of adequate wastewater treatment and disposal facilities, and growing emphasis on demand-side management strategies. Finding additional water supplies and expanding existing wastewater treatment plant capacity is expensive, sometimes impractical and, at best, involves long range planning.

Fortunately, solutions are available which can reduce water consumption and peak demand in an environmentally acceptable manner. A number of devices can help water users reduce consumption and demand without any appreciable impact on lifestyles. Typical of these are low-flow toilets, low-flow shower heads, and faucet flow restrictors. Generally speaking, these have been well received and have become steadily more popular as the cost of municipal water has risen.

Further reductions can be achieved through the use of on-site wastewater treatment and recycling systems that permit reuse of graywater or combined wastewater for landscape irrigation and toilet and urinal flushing. As an example, in the typical household, approximately 34 percent of the water consumed is used in flushing of toilets. The remaining 66 percent of the water for the most part is available for on-site recovery and reuse. On-site wastewater treatment and recycling systems can be used in all types of residential and commercial buildings and in most types of institutional and industrial buildings.

To develop a better understanding of on-site wastewater treatment and recycling technology (including associated costs), regulatory and institutional constraints, and health and safety issues, information was obtained from a variety of sources, including the members of National Association of Plumbing-Heating-Cooling Contractors (NAPHCC), manufacturers, suppliers, and various state and local government agencies.

FINDINGS

Graywater recycling systems currently are being used primarily for sub-surface landscape irrigation (employing the mini-leachfield design) or toilet flushing. They currently are available from less than 20 manufacturers or suppliers. They range from simple systems for residential applications to complex fully automated systems for commercial and industrial applications.

Regardless of their complexity, all graywater systems consist of most or all of the following major elements.

- Storage tank(s) (typically made of fiberglass or industrial-strength plastic)
- Piping (color-coded PVC)
- Filters (polyester, cloth, *etc.*)
- Pump (fractional horsepower)
- Valves (three-way and check)
- Controls (manual or automatic)

When properly installed, operated, and maintained, graywater systems can "recycle" some of the less contaminated household water that usually flows into a sewage or septic system for treatment. This is accomplished through use of various methods and techniques for *collection*, *treatment*, and *disinfection*.

The *collection* system employs dual wastewater piping -- one for graywater and one for blackwater. While the graywater from bathroom sinks, showers, bathtubs, clothes washing machines and laundry sinks is directed to the storage tank, the blackwater piping remains plumbed to the sewer line or septic tank disposal system.

The *treatment* methods employed depend upon the application involved. They include *media filtration*, *collection and settling*, *biological treatment*, *reverse osmosis*, *sedimentation/filtration*, and *other physical treatment*. The most common treatment method currently employed involves the use of media filtration.

Four different *disinfection* techniques are typically used to treat graywater, as well as combined wastewater, for reuse within or outside a building. These techniques involve the use of *ultraviolet irradiation*, *ozone*, *chlorine*, and *iodine crystals*.

Combined wastewater treatment and recycling systems are different from graywater recycling systems in that they collect and treat the total wastewater (graywater and blackwater) for reuse and/or disposal. Of the less than 100 on-site combined wastewater treatment and recycling systems in use, most recycle combined wastewater for toilet and urinal flushing.

Combined wastewater treatment and recycling systems utilize more complex methods, techniques and controls than graywater systems for wastewater collection and treatment. Many systems use combination treatment methods such as *batch processing using aerobic treatment*, *collection, settling, and sand filtration*, or *biological* *treatment with filtration and disinfection.* The disinfection methods typically employed include ultraviolet irradiation or ozone.

Several studies have been performed in the past to document the chemical characteristics of household graywater and combined wastewater. Results indicate that the chemical characteristics of household graywater are as follows: biochemical oxygen demand (BOD) (51% to 80% of combined sewage); phosphorus (58% to 86% of combined sewage); nitrogen (1-33% of combined sewage); and total suspended solids (23-64% of combined sewage). The pH of graywater varies from 5.7 to 7.8. In contrast, little research has been performed to document the bacteriologic characteristics of household graywater or combined wastewater. The limited studies that been performed have produced very diverse data.

On-site graywater and combined wastewater treatment and recycling systems are still not permitted by numerous states and localities. In fact, many states and localities do not even recognize water conservation and on-site water recycling activities. Currently, only 10 states have policies, recommendations, or regulations permitting the use of on-site graywater recycling systems, and only 8 states permit the use of on-site combined wastewater treatment and recycling systems as shown in Table 1. None of the states permit surface discharge of graywater or treated wastewater, unless discharge standards are met.

Several barriers and constraints currently prevent the widespread acceptance and use of on-site wastewater treatment and recycling systems. These include: *lack of statutory regulations*; *restrictive and ambiguous plumbing codes*; *lack of standards for on-site recycled water*; *lack of confidence in standard practice for controlling cross connection*; and *preference for use of reclaimed wastewater from a central municipal wastewater treatment plant rather than from an on-site wastewater treatment and recycling system.*

The initial cost of a graywater recycling system installed in a single-family residential or small commercial application typically ranges from $500, for a basic "no-frills" system, to $5,000, for a fully automated system; the cost of a combined wastewater treatment and recycling system for the same applications ranges from $4,500 to $8,500. Initial cost for combined wastewater treatment and recycling systems in larger commercial and industrial facilities typically are approximately $1.00 per gross square foot. This includes the cost of equipment and installation of components. It also includes the cost of standby sewer connection required by some systems to emergency service and periodic residual solids disposal. Costs not included are building space for equipment and return water plumbing.

Operating costs are related principally to energy and demand. Energy is consumed in on-site graywater and combined wastewater treatment and recycling systems by electric motors that operate pumps and aeration equipment and by disinfection equipment (*e.g.*, ultraviolet lamps). These costs vary widely depending upon the system being considered and, thus, are difficult to document. One manufacturer (Thetford Systems, Inc.) did provide estimates of annual energy consumption for its

Table 1: States with Policies and Regulations on Graywater and Combined Wastewater Treatment and Recycling Systems

States	Graywater	Combined Wastewater Systems	Contact
Alabama			George Holcombe (205) 242-5007
Alaska			Dick Farnell (907) 465-2656
Arizona	✓		Robert Wilson (602) 257-2270
Arkansas			Patrick Harris (501) 661-2171
California	✓	✓	Dave Quinton (916)445-1248
Colorado			Phil Hegeman (303) 331-4564
Connecticut			Arthur Castellavvo (203) 566-1759
Delaware			Ron Graeber (302) 736-4762
Florida			David York (904) 488-4525
Georgia	✓		Bill McGiboney (404) 894-6644
Hawaii	✓		Felix Udasco (808) 543-8288
Idaho			Rick Mallory (208) 334-5845
Illinois			Dave Antonaccia (217) 782-4977
Indiana			Allen Dunn (317) 633-0100
Iowa			Darryl McAllister (515) 281-6682
Kansas			Steve Page (913) 296-1343
Kentucky			Dave Nichols (502) 564-4856
Louisiana			George Robichaux (504) 568-5100
Maine			Ken Meyer (207) 289-5684
Maryland	✓	✓	Jay Prager (410) 631-3652
Massachusetts			Christos Dimisioris (617) 292-5912
Michigan			Tom Hoogerhyde (517) 335-9214
Minnesota			Dave Morisette (612) 623-5517
Mississippi			Ralph Turnbow (601) 960-7696
Missouri			Nix Anderson (314) 751-6090
Montana			Rick Duncan (406) 444-2544
Nebraska			Terry Philippi (402) 471-2541
Nevada			Dale Ryan (702) 686-4750
New Hampshire			Barry Lehneman (603) 271-3505
New Jersey		✓	Bob Berg (609) 984-4429
New Mexico	✓		Bob Kirkpatrick (505) 841-9450
New York		✓	Ralph Stewart (518) 661-2171
North Carolina		✓	Tim Woody (919) 733-2895
North Dakota			Dave Bergsagel (701) 221-5210
Ohio			Tom Grigsby (614) 466-1450
Oklahoma			Dan Hodges (405) 271-7362
Oregon			Sherman Olson (503) 229-6443
Pennsylvania			Milt Lauch (717) 787-8184
Rhode Island			Mark Boucher (401) 227-2306
South Carolina			Leonard Gordon (803) 734-5096
South Dakota	✓		Bill Baer (605) 773-3296
Tennessee	✓		Steve Morse (615) 741-0690
Texas	✓	✓	Sherman Hart (512) 458-7375
Utah			Don Hanson (801) 538-6159
Vermont			Ernie Christianson (802) 879-6563
Virginia	✓	✓	Alan Knapp (804) 786-1750
Washington			Don Alexander (804) 786-1750
West Virginia			Ron Forren (304) 348-2971
Wisconsin			Dave Russell (608) 266-0056
Wyoming			John Harrison (307) 777-7431

graywater systems for applications in hotels, motels, and recreational facilities. These range from 13,000 kWh (for 350 gpd system) to 95,000 kWh (for 8,500 gpd system).

Maintenance costs typically include the cost of replacement parts, replacement labor, filter cleaning labor, equipment repair, and cost of maintaining control systems. For residential and small commercial applications, the annual maintenance cost associated with graywater systems is about $50 to $100, including the cost of filter replacement and labor for periodic maintenance and flushing of the system. For combined wastewater treatment and recycling systems in large commercial and industrial applications, the annual maintenance costs can range up to 15 percent of initial equipment cost or approximately $0.15 per gross square foot.

CONCLUSIONS

Based on the research findings, the following conclusions can be reached.

1. On-site wastewater treatment and recycling systems are a potentially important demand-side management option that can result in significant metered potable water savings (up to 50% reduction and about 75-90% in commercial buildings). Their use also can reduce peak demand on central municipal wastewater treatment plants.

2. Current applications of on-site wastewater treatment and recycling systems generally are being driven by factors such as persistent drought conditions, lack of available sanitary sewers, overloaded central sewage treatment plants, poor site or soil conditions, and water conservation.

3. The initial cost of all on-site wastewater treatment and recycling technologies remains high. This is because the current market remains restricted to those states that face persistent drought conditions, and to those areas where sewer systems are not available or soil conditions do not permit use of conventional septic tank/leach field systems. The lack of national standards, guidelines, and\or regulations is another impediment.

4. Each state and county currently must establish its own standard and develop its own regulations with regards to the use of on-site graywater recycling and combined wastewater treatment and recycling systems. This regulatory process is generally slow and, thus, the market for on-site wastewater treatment and recycling systems remains too small and fragmented.

5. Although there is a growing acceptance that wastewater recycling is an important strategy for water conservation and peak reduction, public health and building officials in many states prefer the use of reclaimed water from central municipal plants rather than the use of recycled water from on-site wastewater treatment and recycling systems. Reclaimed water is preferred because it has superior water quality and offers lower health risks. In addition, centralized operation permits better control over the operation and

maintenance of the system. Also, reclaimed water from central municipal plants is a major revenue source for the localities that employ it. This mind set of public health and building officials continues to limit the widespread use of on-site wastewater treatment and recycling systems.

6. Health and safety risks associated with use of on-site graywater and treated blackwater still are relatively unknown. Further study of the risk involved with various end-uses is required.

7. Although most model or state plumbing codes currently do not address the use of on-site graywater systems or combined wastewater treatment and recycling systems, they do not prohibit use of these systems. An exception to this is the state of California where six counties -- Santa Barbara, San Luis Obispo, Mariposa, Los Angeles, San Bernardino, and San Diego -- have modified their plumbing codes. As a result, code approvals are generally made on a case-by case basis. Note, legislation (Assembly Bill No. 3518) recently has been passed legalizing the use of on-site graywater systems in residential buildings on a statewide basis. The Department of Water Resources has till July 1, 1993 to develop and adopt installation standards for on-site graywater systems.

RECOMMENDATIONS

It is evident that additional research is required. This research should include:

1. Develop guidelines for design and installation of graywater and combined wastewater treatment and recycling technologies. The guidelines should address, at a minimum, the following subjects.

   - Filtration processes for solids separation
   - Chlorination and other disinfection processes
   - Chemical treatment
   - Biological treatment
   - Use of defoaming agents for recharging of water
   - Pipe sizing and materials selection
   - Pipe identification
   - Cross connection controls
   - Pump sizing and design
   - Corrosion control
   - Effluent discharge facilities

2. Develop guidelines for operation and maintenance for alternative wastewater treatment and recycling systems for use by appropriate facility personnel. The guidelines should cover the following subjects.

   - Control systems
   - System operation
   - Maintenance frequency and methods

- Annual maintenance and parts inventory
- Contracted services (*e.g.*, residual solids removal and wastewater management services)

3. Demonstrate the validity of recommended systems, guidelines, and practices through on-site testing at representative sites. These sites should differ in terms of location, type of system involved and type of application (residential, commercial, and industrial). Each site should be monitored for a period of one year in order to determine if concepts, procedures, and recommendations suggested are practical and cost-effective. Other information that should be evaluated includes the following subjects.

   - Appropriateness and comprehensiveness of design guidelines
   - Inadequacy of design documentation (drawings and specification)
   - Problems encountered during installation
   - Corrective measures undertaken
   - Reliability of system operation
   - Adequacy of recommendations for maintenance

4. Develop and implement stringent controls and standards for graywater recycling systems. These controls and standards should include the following subjects.

   - Set back requirements
   - Construction requirements
   - Minimum percolation rates and soil absorption characteristics
   - Minimum specifications pertaining to construction materials
   - Cross-connection control requirements

5. Develop a model regulatory program. This should include the following elements.

   - Permitting of uses
   - Licensing of graywater system on a local basis
   - Installation inspection and plan checking
   - Program funding through permit or user fees
   - Enforcement sanctions for violations of standards

6. Develop a modified model plumbing code which incorporates provisions for the installation and use of on-site graywater and combined wastewater treatment and recycling systems.

7. Develop end-user education materials. These materials should address the following subjects.

   - Health risks
   - Operation and maintenance requirements
   - Economics

I. INTRODUCTION

Although fresh water is one of America's most precious resources, many Americans consume far more water than they really need while drought conditions persist in many areas of the U.S. Compounding this problem, many of the aging sewage and water treatment systems in the United States are incapable of meeting the demands placed upon them due to increasing population and economic growth. In many urban areas, water and wastewater treatment plants are overloaded and plagued by operational problems due to years of neglect and deferred maintenance.

Finding additional water supplies and expanding existing wastewater treatment plant capacity is expensive, sometimes impractical, and involves long-range planning. Fortunately, America is beginning to recognize the limits of its natural resources and the need to act in a more environmentally responsible manner to protect them. Accordingly, the time has come to do more than simply attempt to keep up with traditional water usage patterns. If significant change in water use patterns is to be effected, it will be essential to modify the behavior of people who consume water. As significant a task as this may seem, it already has been undertaken in other areas -- as when the electrical industry initiated a demand-side management concept. Through this approach, electrical utilities around the nation developed a variety of incentives which encouraged consumers to reduce their unnecessary use of electricity. These conservation programs are working very well; as a result, numerous electrical utilities have been able to defer construction of new generating facilities for decades.

A number of devices now are available to help water users conserve by reducing consumption and demand without any appreciable impact on lifestyles. Typical of these devices are low-flow toilets, low-flow shower heads, and faucet flow restrictors. Generally speaking, these have been well received and have become steadily more popular as the cost of municipal water has risen.

A significantly overlooked area of water conservation, however, has been the potential for reuse of water on-site. As an example, in the typical household, approximately 34 percent of the water consumed is used in flushing of toilets. The remaining 66 percent of the water, except that used in the kitchen, can be recovered for reuse by on-site wastewater treatment and recycling systems for purposes such as landscape irrigation and flushing of toilets and urinals.

On-site wastewater treatment and recycling systems potentially can be used in all types of residential, commercial, institutional, and industrial buildings. However, their application in these buildings has been limited to date due to a variety of factors, including: restrictive regulations and plumbing codes; lack of standards for recycled water quality; and perceived health and safety risks and impacts.

OBJECTIVE

The overall objective of this project was to assess graywater and combined wastewater treatment and recycling technology currently available for residential, commercial, institutional, and industrial applications. Specific project objectives were to:

- Determine cost-effectiveness of available technologies.
- Evaluate regulatory and institutional (*e.g.*, codes and standards) constraints that hinder the widespread adoption of graywater and combined wastewater treatment and recycling technologies.
- Evaluate health and safety issues related to implementation of available technologies.

RESEARCH METHODOLOGY

Information for this project was gathered through literature searches and contacts with various associations, federal and state agencies, manufacturers, and research institutes. A survey of state requirements was undertaken in order to develop information on state regulations and applicable plumbing codes relative to graywater and combined wastewater treatment and recycling systems. Furthermore, all information collected was reviewed and analyzed to assure its comprehensiveness and accuracy.

II. CHARACTERISTICS OF WASTEWATER

Historically, public policy, and health codes have encouraged, if not mandated, centralized collection and treatment of all household wastewater in urban areas whenever possible. Segregation of individual waste sources into graywater and blackwater streams generally has not been permitted by local building officials and health departments. However, this situation is changing, particularly in California where several counties and cities now allow the use of graywater.

Graywater is used household water generated by clothes washing machines, showers, bathtubs, and bathroom sinks. It usually does not contain water used in the kitchen. The amount of oil, fat, and grease from dishwashing makes kitchen water smelly and difficult to filter, likely to clog distribution pipes, and even more likely to attract pests. However, an important exception to this general rule would be a double kitchen sink with two separate drain pipes. One side can be hooked up to the sewer or septic tank to receive all the greasy, oily, or cleanser-laden wastes, while the other side can be connected directly to the graywater system and only receive dish-washing rinse water and water used to clean vegetables.

Blackwater is water that is flushed down toilets and urinals. This water cannot be directly reused. It must be: disposed to a sanitary sewer for treatment and disposal by a central treatment plant; treated and disposed of on-site (*e.g.*, by a septic tank and leach field); or treated and recycled by an on-site wastewater and recycling system.

Due to the drought and water shortages in many parts of the country, and lack of adequate wastewater treatment and disposal facilities, public policy and health codes regarding graywater are being reexamine. Although graywater is difficult to characterize because the number of household appliances and occupant use practices vary greatly, several studies have been conducted in the past to study the characteristics of typical household wastewater as well as how various pollutants are distributed between the graywater and blackwater waste streams. A brief discussions of finding is as follows.

HOUSEHOLD WASTEWATER GENERATION

Table 2-1 presents data on the volumes of household wastewater typically generated and average pollutant concentrations as reported by various investigations.

CHEMICAL QUALITY

The chemical parameters of concern in wastewater traditionally have included biochemical oxygen demand (BOD, suspended solids, nitrogen, and phosphorous. For reuse in irrigation, total dissolved salts and "trace" chemicals such as boron also are important.

Table 2-1: Average Pollutant Discharge in Household Wastewater (mass/capita/day)[1]

Pollutant \Study	Olsson (1)	Wallman (2)	Ligman (3)	Laak (4)	Bennett (5)	Siegrist (6)	Average g/c/d	Mean mg/1
BOD_5	45.0		48.1	48.6	34.8	49.6	45.2	260
Suspend-ed Solids	48.0		46.3		47.3	35.1	44.2	260
Nitrogen	12.1		16.8		7.2	6.1	10.6	62
Phosphor-us	3.8		4.1			4.0	4.0	23
Flow, gal/c/d	52.1	52.0	46.0	41.4	43.7	36.5	45.3	

[1]The results are for households with typical appliances excluding garbage disposals. All pollutant contributions are expressed in grams/capita/day (g/c/d) except flow, which is in gallons/capita/day (gal/c/d), and the mean concentration, which is in mg/1.
Source: Reference #7

BOD of graywater varies greatly (from 51% to 80% of combined household sewage or about 75 - 400 mg/1) as shown in Table 2-2. Kitchen sink water provides the heaviest BOD loading of all graywater fixtures (40% to 70% depending on laundry use) as shown in Table 2-3. The BOD loading, however, is much more soluble than combined sewage. There is no toilet paper and no feces. As a result, the graywater BOD should be more easily biodegraded than BOD in combined sewage.

Between 58% and 86% of the phosphorus in combined sewage is found in graywater, most originating from laundry water. Note, the phosphorus content of graywater depends upon the formulation and composition of the detergents used, *e.g.*, low phosphate detergents produce less phosphorus in laundry water. Nitrogen comes predominately from urine and feces (67% to 99%). Most of the nitrogen in graywater comes from the laundry.

The amount of suspended solids is an important consideration when reuse involves hose nozzles or any other restrictions in the water delivery line. Graywater contains about 39% of the total suspended solids of combined sewage.

A continuing study by Karpiscak et al. (8) conducted Casa del Agua in Tuscon, Arizona has shown that pH of graywater varies from 5.7 to 7.8 with a mean of 7.1. Additional parameters being studied include, but are not limited to: phosphate, sulfates, ammonia, BOD, turbidity, alkalinity, and chlorides.

Depending on the home, graywater accounts for 53% to 81% of all water used in a typical, residential home as shown in Table 2-2. Siegrist (7) estimates average of 65% of household wastewater is graywater. It equals roughly to 29.4 gallons per capita per day. An estimate of the proportion of graywater in a suburban home is shown in Figure 2-1.

In some rural (versus suburban) situations, the proportion of graywater volumes may be much less. When water is gravity-fed, hand-pump, or hand-carried, water conservation practices often are followed, and a per capita flow of 10 gallons of graywater each day can be expected.

BIOLOGICAL QUALITY

In addition to the chemical/physical contributions shown in Tables 2-1 and 2-2, bacteriological characteristics also are of interest. Since very little research has been performed on raw individual household wastewater, the bacteriological content determined in household septic tank effluent are presented in Table 2-4. Although the values presented are for septic tank effluents, rather than raw wastewater, they do give an idea of the bacteriological character of typical individual household wastewater. As shown in Table 2-4, effluents from septic tanks receiving combined household wastewater were found to consistently contain significant concentrations of indicator bacteria and pseudomonas aeruginosa. Staphylococcus aureus and salmonellae also were isolated, but only infrequently and in much lower concentrations (Table 2-5).

Table 2-2: Pollutant Division Between the Black and Gray Wastewater Streams[1]

POLLUTANT	GRAY	GRAY	GRAY	GRAY	BLACK	BLACK	BLACK	BLACK
	Mean %	Range %	Mean g/c/d	Mean mg/l	Mean %	Range %	Mean g/c/d	Mean mg/l
BOD_5	63	51-80	28.5	255	37	20-49	16.7	280
Suspended Solids	39	23-64	17.2	155	61	36-77	27.0	450
Nitrogen	18	1-33	1.9	17	82	67-99	8.7	145
Phosphorus[2]	70	58-86[2]	2.8	25	30	14-42	1.2	20
Flow	65	53-81	29.4		35	19-47	15.9	

[1]The values shown are based on the results of the studies used to compile Table 1. The results are average values for households with typical conventional appliances, excluding the garbage disposal.
[2]The composition of graywater is dependent upon the formulation and composition of detergents used.
Source: Reference #7

Table 2-3: Mean Wastewater Characteristics (mg/l)

	Garbage Disposal	Kitchen Sink	Automatic Dishwasher	Clothes Washer	Bath/ Shower	Composite[1]
BODs	1030	1460	1040	270	170	609
TOC	690	880	600	200	100	1135
TS	2430	2410	1500	880	250	376
TVS	2270	1710	870	350	190	719
TSS	1470	720	440	200	120	389
TVSS	1270	670	370	120	85	316
TOT-N	60	74	40	13.5	17	30.5
NH_3-N	0.9	6	4.5	0.6	2	2.5
NO_3-N	0	0.3	0.3	0.5	0.4	0.36
TOT-P	12	74	68	39	2	37.6
PO-P[2]	8	31	32	10	1	14.9
Flow Gallons	3.8	4.8	12.0	15.1	13.0	48.7

[1]Computed as a flow weighted value.
[2]The composition of graywater is dependent upon the formulation and composition of detergents used
Source: Reference #9

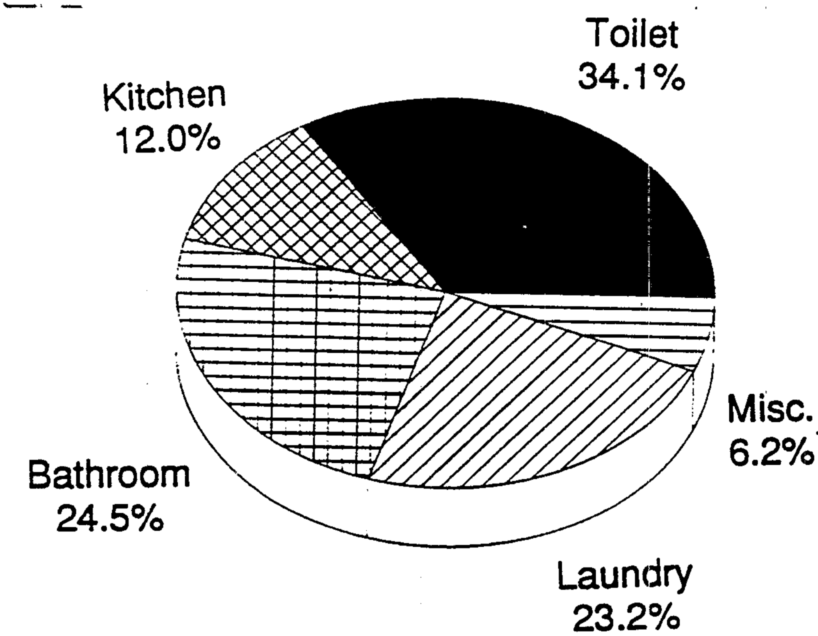


Figure 2-1: Proportions of Graywater in a Typical Suburban Home

Intuitively, one might expect that the majority of these organisms in combined household wastewater exist in toilet wastes, with only low levels in the graywater. To evaluate this hypothesis concerning graywater, Seigrist (10) conducted field studies at the University of Wisconsin. In-house samples of the wastewater produced by two sources, bathing and clothes washing, were obtained from each of six households in the experiment over a two-week period. Bacteriological analyses were performed for total and fecal coliforms and fecal streptococci. The summarized results of the study are presented in Table 2-6. As shown, the results demonstrate that a wide range of indicator organisms can be expected in the raw bath and laundry wastewaters, which in turn indicates a potential for pathogen contamination.

Table 2-4: Bacteriological Quality of Household Septic Tank Effluent (Bacteria/100 mls)

Organism	Data Points[1]	Mean[2]	95% Confidence Interval
Fecal Streptococci	97	3800	2000-7200
Fecal Coliform	94	420,000	290,000-620,000
Total Coliform	91	3,400,000	2,600,000-4,400,000
Pseudomonas Aeruginosa	33	8600	3800-19,000
Total Bacteria	88	34×10^7	$25\text{-}48 \times 10^7$

[1]The results are for samples from septic tank effluents at five residences.
[2]Log normalized data.
Source: References #7 and #16

Table 2-5: Frequency of Staphylococcus Aureus and Salmonella Spp. in Septic Tank Effluent

HOUSEHOLD	**Staphylococcus Aureus**		**Salmonella spp.**	
	Total Samples	**Positive Samples**	**Total Samples**	**Positive Samples**
A	16	0	8	0
B	14	1	6	0
C	5	3	1	0
D	6	0	3	0
E	8	1	10	0
F	7	1	9	1
G	4	0	-	-
H	1	0	6	0
I	1	0	7	0
J	1	0	1	0
K	-	-	2	0
L	-	-	2	1
TOTALS	63	6	55	2
Range of Concentrations	10/100 ml			

Source: References #7 and #16

Table 2-6: Selected Bacteriological Characteristics of Bath and Laundry Wastewaters (Seigrist)[1]

Event	Organism	Samples	Mean[2] #/100 ml
Clothes Washing[3]	Total Coliforms Fecal Coliforms Fecal Streptococci	41 41 41	215 107 77
Bathing	Total Coliforms Fecal Coliforms Fecal Streptococci	32 32 32	1810 1210 326

[1]The results shown are based on in-house event sampling at each of six households.
[2]Log-normalized.
[3]Samples were obtained from the middle of the wash cycle. Samples taken from several rinse cycles also were consistently lower than the corresponding wash cycle values.
Source: Reference #7

To gain a better understanding of the actual magnitude of this "potential," Seigrist (6) also evaluated several of the samples for two common pathogens, pseudomonas aeruginosa and staphylococcus aureus. He found a very low incidence of pseudomonas aeruginosa and very low concentrations (below 20/100 ml) when present. Staphylococcus aureus was not found. A comparison of selected bacteriological characteristics in various household wastewater streams is shown in Table 2-7. Based on these findings, Seigrist (7) concludes "...the low pathogenic contamination of these [laundry and bath] waters would seem to indicate a low potential pathogenic contamination in graywater as a whole. Thus, while the raw graywater is not innocuous, its potential contamination appears to be substantially lower than that of either the toilet wastes or combined household wastewater."

There have been other studies that have examined bacteriological characteristics of graywater as well. These findings are very different from that reported above. They are summarized in Table 2-8.

Brandes (11) found fecal coliform bacteria concentrations in graywater samples in the same range of magnitude as usually observed in septic tank effluent generated from all domestic sources. Boyle et al (12) reported that residential graywater contained substantial amounts of pollutants, including fecal coliform bacteria, BOD_5, suspended solids, nitrogen, and phosphorus. The State of California Department of Health Services (13) reported that the average bacteria concentrations were roughly 8,000,000 most probable number (MPN) total coliform organisms/100 milliliters (ml) and 400,000 MPN fecal coliform organisms/100 ml in water from the bathtub or

Table 2-7: Comparison of Selected Bacteriological Characteristics in Various Household Wastewater Streams (#/100 mls)

Organism	**Combined Septic Tank Effluent**[1]	**Black Water**[2]	**Graywater**[3]
Total Coliforms	3,400,000	6,300,000	1810
Fecal Coliforms	420,000	5,000,000	1210
Fecal Streptococci	3,800	-	326
Pseudomonas Aeruginosa	8,600	-	0-20
Staphylococcus Aureus	10-1000	-	0

[1]Mean values
[2]Based on the values determined by Olsson et al. (1) as diluted in four toilet flushes of five gallons each.
[3]Based on the highest mean value determined in the bath and clothes washing sampling, Tables 2-5 and 2-6.
Source: Reference #7

Table 2-8: Bacteriological Characteristics of Graywater

	Brandes (11)	**Boyle et al. (12)**	**Calif. D.H.S. (13)**
Total Coliform/ 100ml	60,000- 134,000,000	7,943,282	8,000,000[A] 3,000 - 50,000,000[B]
Fecal Coliform/ 100ml	5,000-21,000,000	1,905,461	400,000[A] 2,000- 10,000,000[B]

[A]Samples from bathtub or shower
[B]Samples from washing machines
Source: Reference #14

shower, and 3,000 to 50,000,000 MPN total coliform organisms/100 ml and 2,000 to 10,000,000 MPN fecal coliform organisms/100 ml in water from washing machines.

Rose et al. (15) observed reductions of up to 99.9% in standard plate count, total coliform, and fecal coliform concentration of 7.08×10^8, 3.89×10^7, and 1.07×10^6, respectively, in graywater after passage through aquacells planted with water hyacinths, sand filtration, and storage.

It is obvious from these limited studies that data on bacteriological characteristics is quite variable. More study of health risks (dose, organisms, comparative risks, *etc.*) from actual use of graywater is needed. The City of Los Angeles currently is performing a comprehensive study of graywater systems. The primary objective of the study is to obtain reliable quantitative data from actual use of graywater systems for irrigation at eight residential sites located in the City of Los Angeles.

Because monitoring, testing, sampling, and analysis are the key to the success of the Los Angeles project, guidelines for appropriate parameters of observation at the optimum sampling frequency, along with controls to allow for statistical analysis and comparison of the data, have been predetermined. At every site, composite soil and stored water samples are being obtained for analysis at a laboratory under contract with the Department of Water and Power (DWP). Additional control samples are being obtained at half of the sampling events from areas not irrigated with graywater. Prior to start of graywater irrigation, samples of soils have been obtained to establish baseline conditions.

Anytime standing water is observed at irrigation sites, whether in dry weather or after a rainfall, water, and soil samples are being conducted on a monthly basis, with specific days of the month assigned to specific sites. Each sample is labeled immediately after collection. Labels are attached, prior to sample collection in a prescribed manner to prevent removal, confusion, or inadvertent switching. Samples are immediately refrigerated at 4°C and transported to a certified laboratory for analysis.

All samples are being analyzed for the following biological and chemical parameters, within 24 hours after sample collection:

- Biological Parameters
  - -- Total coliform
  - -- Fecal coliform
  - -- Enterococci
  - -- Salmonellae
  - -- Shigellae
- Chemical Parameters
  - -- pH
  - -- Total dissolved solids
  - -- Sodium
  - -- Calcium
  - -- Magnesium
  - -- Chloride

At monthly intervals - but not necessarily coincidental with sampling - visual observation notes are being taken at every site, supplemented with photography. The following information is being recorded.

- Condition of connections, valves, fittings, appliances
- Condition of storage tank, if applicable

- Condition of filter, if applicable
- Condition of irrigation system (clogging, slime, rupture, *etc.*)
- Evidence of water on the soil surface
- Evidence of runoff (including nature and extent)
- Complaints, if any
- Estimate of volume of water saved in the preceding month
- Adequacy of operation and maintenance
- Evidence of excessive storage time in the storage tank
- Evidence of mosquitoes in storage tank, application areas
- Meter readings, including water meter and graywater meter

Although the study will not be completed until the end of 1992, the Office of Water Reclamation has developed and issued a report (17) summarizing findings, conclusions, and recommendations based on data collected during the first six months. The report concludes that use of graywater at pilot sites, even with surface application, does not pose a significant risk to the users or the community. It lists certain generalizations in support of this conclusion.

- Indicator bacteria in the soil generally do not seem to increase with graywater application.
- Disease organisms, normally capable of surviving in the soil for a few days, are not present in graywater irrigated areas. Neither have these organisms been detected in the graywater sampled form storage tanks.
- Individuals assigned the task of cleaning graywater filters have not reported any adverse effects.

III. GRAYWATER RECYCLING SYSTEMS

Traditionally, on-site septic tank/leach fields and centralized municipal sewage treatment facilities have been the primary source of water disposal for single-and multi-family residential buildings and complexes. But, as long-term water shortages increase, and water conservation becomes more of a national issue, various on-site water treatment and recycling technologies are being more actively explored. One possible source that is receiving much public attention is *graywater* recycling.

This section presents a comprehensive overview of graywater, including: *graywater uses*; *basic system concepts*; *currently available technologies*; *current and potential applications*; *application considerations*; *installation considerations*; *operation and maintenance considerations*; and *potential impact of graywater use on the sewer system.*

GRAYWATER USES

Graywater is being used in many areas of the U.S. Although it is being used primarily for *landscape irrigation* and for *toilet and urinal flushing*, it can be used for other purposes as well. A brief description of these end-uses follows.

Landscape Irrigation

A significant amount of water is used in a typical home for landscape irrigation. In some areas of the U.S., particularly in semi-arid and arid areas of the Southwest, it can account for 50 percent of total household water use. Because an average of 20 to 40 gallons of graywater per person per day are produced in a typical home, graywater could meet most, if not all, of the irrigation water needs of the trees, shrubs, and lawn for many homes.

When graywater is used for landscape irrigation, it is further purified by the biological activity in the topsoil. Soil microorganisms break down organic matter while plants take up nutrients.

Toilet and Urinal Flushing

Treated graywater can be used as flush water for toilets and urinals. It's use in residential applications of this type, however, has been limited.

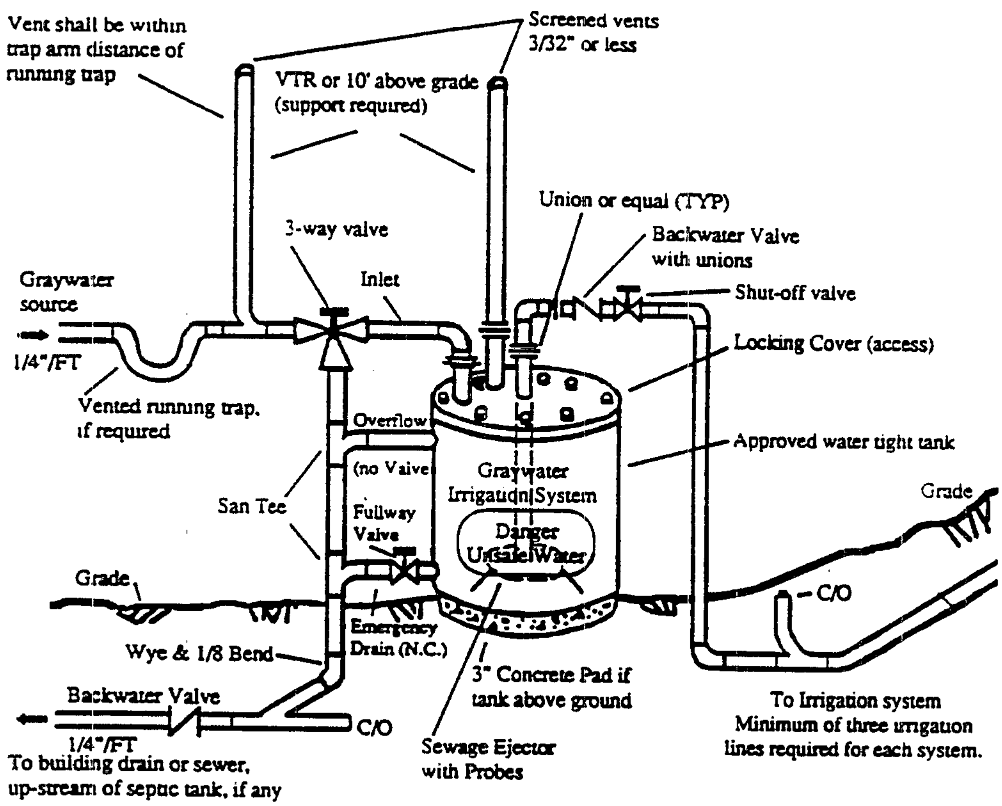
Other Uses

Graywater also can be used as supply water for ornamental ponds and make-up water for cooling towers used in many central air-conditioning systems.

BASIC SYSTEM CONCEPTS

Graywater systems range from simple systems for residential applications (Figure 3-1), to complex, fully automated systems for commercial and industrial applications. Regardless of their complexity, all graywater systems include most or all of the following major elements.

- Storage tank(s) (typically made of fiberglass or industrial-strength plastic)
- Piping (color-coded PVC)
- Filters (polyester, cloth, *etc.*)
- Pump (fractional horsepower)
- Valves (three-way and check)
- Controls (manual or automatic)



Abbreviations

C/O Cleanout
N.C. Normally Closed
VTR Vent Thru Roof

Figure 3-1: Graywater System for Landscape Irrigation
Source: Reference #18

When properly installed, operated, and maintained, graywater systems can "recycle" much of the household water that otherwise would flow into a sanitary sewer or septic system for treatment. This is accomplished through use of various methods and techniques for collection, treatment, disinfection, and irrigation. A brief description of these methods and techniques follows.

Collection Methods

A graywater recycling system requires the use of a dual wastewater piping system in a building -- one for graywater and one for blackwater. Separate graywater piping is needed to collect wastewater from bathroom sinks, showers, bathtubs, clothes washing machines, and laundry sinks and to direct it towards the storage tank. Any alterations in the piping must be approved by the local building inspector. It is necessary to consult with the local building, heath or water department to find out what restrictions apply.

The blackwater piping from toilets and kitchen sink remains plumbed to the sewer line or septic tank disposal system. In retrofit situations involving buildings with slab foundations, the graywater that can be recovered may be limited to the clothes washing machine. Most drain pipes are buried beneath the slab and, thus, are not easily accessible without a significant additional expense. Those buildings with perimeter foundations permit access to graywater piping from the crawl space and, thus, most of the graywater is recoverable.

Treatment Methods

A variety of methods can be used for treating the graywater for reuse purposes. These include the use of: *media filtration*; *collection and settling*; *biological treatment units*; *reverse osmosis*; *sedimentation/filtration*; and *physical/chemical treatment*. Depending on the graywater source, application, recycling scheme and economics, one method may be more appropriate than the other.

Media Filtration

Several different types of media can be used in graywater filtration. These include: *nylon or cloth filters*, *sand filters*, and *rack or grate filters*. Each is described briefly below.

Nylon or Cloth Filter: The nylon or cloth filter system typically consists of a filter bag connected to the graywater inlet pipe in a tank. The graywater is passed through the filter media (which collects lint and hair) and collected within the tank. Once filtered graywater is collected, the treated graywater typically then is pumped to a mini-leachfield for irrigation purposes. This system currently is recommended by the City of Santa Barbara and City of San Luis Obispo in California for use in recovering washing machine water for irrigation purposes.

Sand Filter: The sand filter system consists of a sand- and rock-filled tank with an underdrain system (Figure 3-2). Graywater is poured onto splash plates. The graywater then seeps through the filter media, receiving both physical and biological treatment. Biological treatment occurs by bacterial growth on the sand which breaks down organic matter and extracts nutrients from wastewater to support growth. Physical filtering removes solids and results in clarification of the wastewater. The filtered graywater then is collected and transported via an underdrain system for reuse. A pea gravel filter is similar to a sand filter except that it uses pea-sized stone instead of sand for filtration.

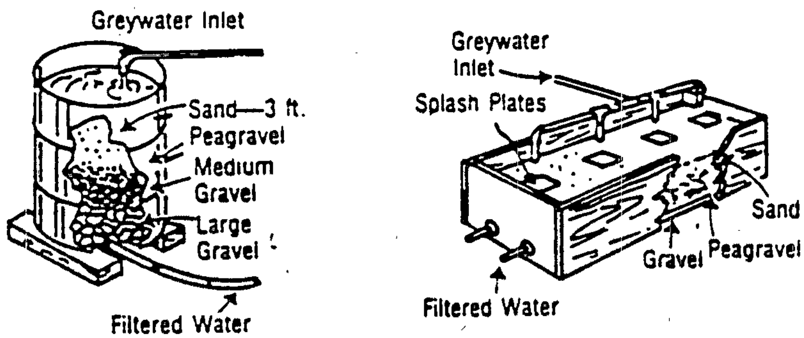


Figure 3-2: Sand Filters
Source: Reference #9

The University of Wisconsin (9, 22) evaluated sand filters for treating graywater septic tank effluent and obtained 98 percent removal of biological oxygen demand (BOD) and greater than 75 percent removal of chemical oxygen demand (COD), total suspended solids (TSS), and volatile suspended solids (VSS). The study concluded that intermittent sand filtration of graywater septic tank effluent resulted in almost complete nitrification. Effluent phosphorus levels largely remained unchanged.

Diatomaceous Earth Filter: Diatomaceous earth filters have been commonly used to filter water for swimming pools and spas. They also can be used for treating graywater. Cohen and Wesner (19) evaluated the use of a diatomaceous filter system with a recycle line to treat graywater and concluded that turbidity and suspended solids were reduced to 13 to 30 mg/l and 15 to 25 mg/l, respectively. Hypes, Batten, and Wilkins (20) modified Cohen and Wesner's filter in the recycle line and reported reductions of turbidity to 29 mg/l, TOC by 19 percent, and coliforms by 100 percent.

Rack or Grate Filter: The primary function of the rack or grate filter is to remove particulate matter from the graywater. The graywater system typically consists of a rack or grate filter, piping, and a tank. Graywater is passed through the filter media into the tank. The graywater then is either further treated or reused.

Collection and Settling

Collection and settling systems employ techniques commonly used for treatment of combined graywater and blackwater. One example of this system involves the use of a septic tank. Septic tanks provide for the retention of the solids portion of graywater and anaerobic treatment of the liquid generally for three to five days. The septic tank allows solids from incoming graywater to settle to the bottom of the tank, forming a sludge layer. Certain materials, such as grease and hair, float to the top of the liquid in the tank and form a floating scum layer. This scum layer is held in the tank by baffles. The liquid effluent flows through an outlet pipe for further treatment or reuse.

The University of Wisconsin (21) evaluated the performance of different sized septic tanks (500- and 1,000-gallon) and found that the larger tank achieved an additional 17 percent reduction in BOD and 15 percent reduction in COD, with little further reduction of solids or nutrients.

Brandes (11) and Olsone et al (22) evaluated graywater septic tank effluent characteristics based upon extensive data collection programs. Brandes (11) concluded that time intervals that could be allowed between graywater septic tank cleanouts were about eight to ten times longer than for normal household septic tanks treating combined wastewaters.

Biological Treatment Units

Biological treatment of graywater is a means of reducing both soluble and insoluble organic contaminants. These units usually consist of three chambers: pre-settling, aeration, and final settling (with sludge return). Graywater first flows into the pre-settling chamber where gross solids settle out. The effluent from the pre-settling chamber then flows into the aeration chamber where biological action reduces soluble organics. The effluent then flows into the final settling chamber where biologically active solids settle out. Biological treatment units usually are used in large commercial applications.

Reverse Osmosis

Reverse osmosis (RO) units have been tested for graywater treatment. The RO system consists of storage tanks, pumps, filtration units, and a reverse osmosis module. Graywater is collected and stored in a storage tank (Figure 3-3). The graywater then is pumped through filtration unit(s). The filtered graywater them flows to a second tank, and is pumped to the reverse osmosis unit. The filtered graywater which passes through the reverse osmosis unit is stored for reuse/disposal.

Hypes, Batten, and Wilkins (23) examined the performance of a sedimentation/reverse osmosis unit to treat laundry and shower wastewater and reported reductions in total solids (TS) and total organic carbon (TOC) of 88 percent and 93 percent, respectively. The study concluded that the effluent water met all Public Health Service drinking water requirements except for carbon chloroform extract (CCE), methylene blue - active substances (MBAS), and phenols.

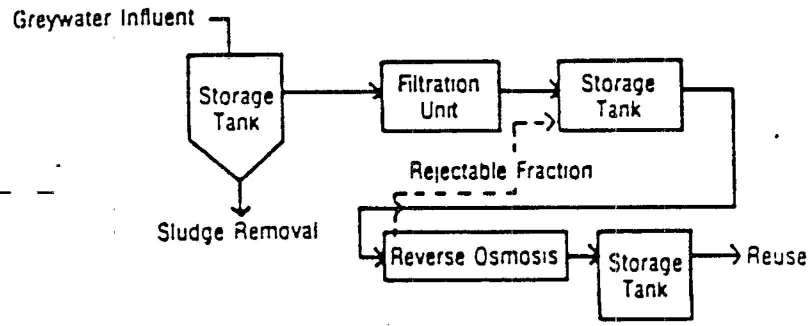


Figure 3-3: Reverse Osmosis
Source: Reference #9

Sedimentation/Filtration

A variety of different designs of sedimentation/filtration treatment schemes exist. These systems are basically the same with minor variations in sedimentation basin design, filter media, and recycling rates. The basic design consists of a conically shaped storage/settling tank and a filter. The shape of this tank, along with a bottom drain, simplifies sludge removal. The storage tank also should be equipped with an overflow fitting and low-level control to assure adequate water supply at all times. A variety of filters can be used. Cartridge filters are very convenient because they are discarded when spent. Diatomaceous earth filters also have been used. Activated charcoal filters have been used in conjunction with diatomaceous earth filters. The treated graywater is disinfected and then reused/disposed (Figure 3-4).

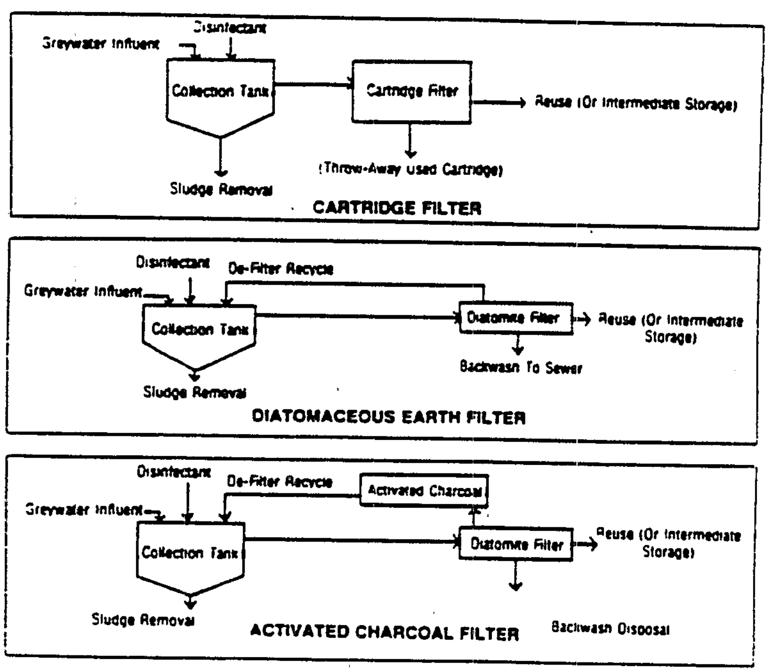


Figure 3-4: Sedimentation/Filtration Systems
Source: Reference #9

Physical/Chemical Treatment

In this process, graywater flows through a rapid mix tank where polymer and activated carbon are added. The mixture of graywater, polymer, and carbon flows to a clarifier where a sludge conditioner is added. After settling, the supernatant then is disinfected and passed through a diatomaceous earth filter. The treated graywater then is ready for reuse for toilet flushing or lawn watering.

Lent (24) used a chemical coagulation with polymer and activated charcoal system to treat graywater. He reported an effluent with BOD, suspended solids, and turbidity removal exceeding 90 percent.

Disinfection Techniques

Four different techniques have been used to treat graywater for reuse within or outside buildings. These techniques involve: *ultraviolet irradiation, ozone, chlorine*, and *iodine*. A brief description of each disinfection technique follows.

Ultraviolet Irradiation

Ultraviolet irradiation (UV) disinfection involves passing graywater under a lamp which emits light within the ultraviolet range that effectively kills any microorganisms. For effective disinfection by UV, the graywater must be free of particulate matter which could prevent the UV radiation from reaching and destroying the microorganisms.

Research performed at the University of Wisconsin (25) and by Hoover, McNalfy, and Goldsmith (26) investigated the performance of disinfecting sand filter effluent and aerobic unit effluent with UV. Their findings revealed that fecal coliform, total coliform, fecal streptococci, total bacteria, pseudomonas aeruginosa, and poliovirus I populations were reduced by at least 97 percent in all cases.

Ozone

Ozone is a highly reactive form of oxygen. It is formed naturally by the short wave ultraviolet light of the sun reacting with oxygen in the upper atmosphere. The ozone layer protects us from receiving the harmful shortwave radiation from the sun by absorbing it.

As shown in Table 3-1, ozone is a powerful oxidant that can be used safely for disinfection of graywater. When combined with ultraviolet light, ozone forms hydroxyl radicals, which have even a higher oxidation power. For graywater treatment, it has the ability to destroy algae, bacteria, and viruses and to oxidize most organic and inorganic contaminants.

Table 3-1: Relative Oxidation Power of Oxidizing Species

Species	Oxidation Potential (Volts)	Relative Oxidation Power
Fluorine	3.06	2.25
Hydroxyl Radical	2.80	2.05
Atomic Oxygen	2.42	1.78
OZONE	2.07	1.52
Hydrogen Peroxide	1.77	1.30
Perhydroxyl Radicals	1.70	1.25
Hypochlorous	1.49	1.10
Chlorine	1.36	1.00

[1]Based on Chlorine as reference (=1.00)
Source: Reference #27

Large doses of ozone can be harmful to humans. The U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) has set a limit of 0.1 ppm in air as the maximum average exposure for a single 8-hour shift in a 40-hour work week. A person does not become irritated from ozone until the concentration reaches over 100 ppm for one minute. The toxic level is over 1000 ppm for one minute. A well designed ozone system for graywater disinfection, however, does not produce ozone concentrations that are harmful or irritating to humans.

Chlorine

Chlorine in the form of tablets is the most commonly used method of graywater disinfection currently in residential applications. Chlorine tablets are dissolved in the effluent storage tank. Adequate time (about 30 minutes) must be given for bacterial reductions to occur.

Saver (28) at the University of Wisconsin used a dry feed chlorine unit to disinfect sand filter effluent and reported greater than 90 percent reductions in fecal coliform, total coliform, fecal streptococci, total bacteria, and pseudomonas aeruginosa populations.

Iodine

Iodine crystal units operate in the same manner as chlorine tablets. Due to the limited solubility of iodine, a dosing pump is required to assure adequate pressure and flow of wastewater for iodine crystal dissolution.

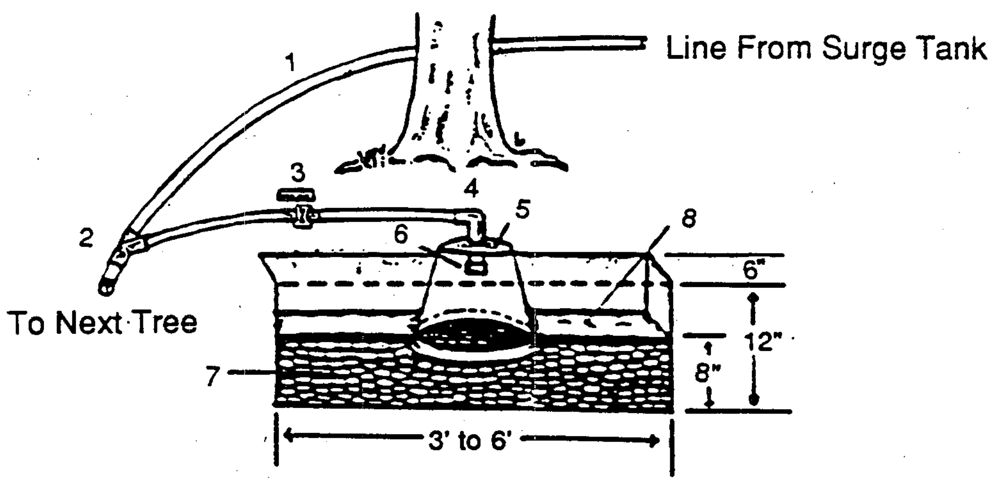
Budde, Nehm, and Boyle (29) investigated iodine crystal units to disinfect treatment plant effluent and reported that greater than 98 percent reductions in coliform bacteria occurred when using a 5 mg/l or greater iodine dose.

Irrigation Methods

Graywater use for landscape irrigation has been approved in several states. However, approved use in all cases is limited to the use of sub-surface irrigation system only. Two types of sub-surface irrigation systems have been used: a mini-leachfield or a drip-irrigation system. Each system is described briefly below.

Mini-Leachfield

A mini-leachfield typically is created by digging trench along the dripline (the outer edge of the foliage) and filled with gravel to within 4 inches of the surface, as shown in Figures 3-5 and 3-6. The gravel is covered with building paper or weed-stop matting before filling the trench with soil. If the soil is able to infiltrate down into the gravel, the mini-leachfield will quickly clog and the water will be forced to the surface, causing pooling.



#1 1/2" polyethylene irrigation hose
#2 'T' coupler
#3 drip irrigation ball valve
#4 right angle coupler
#5 clay (or plastic) pot
#6 straight coupler (used inside pot)
#7 mini-leachfield (1" round gravel)
#8 weed-stop matting or building paper

Figure 3-5: Mini-Leachfield Design
Source: Reference #30

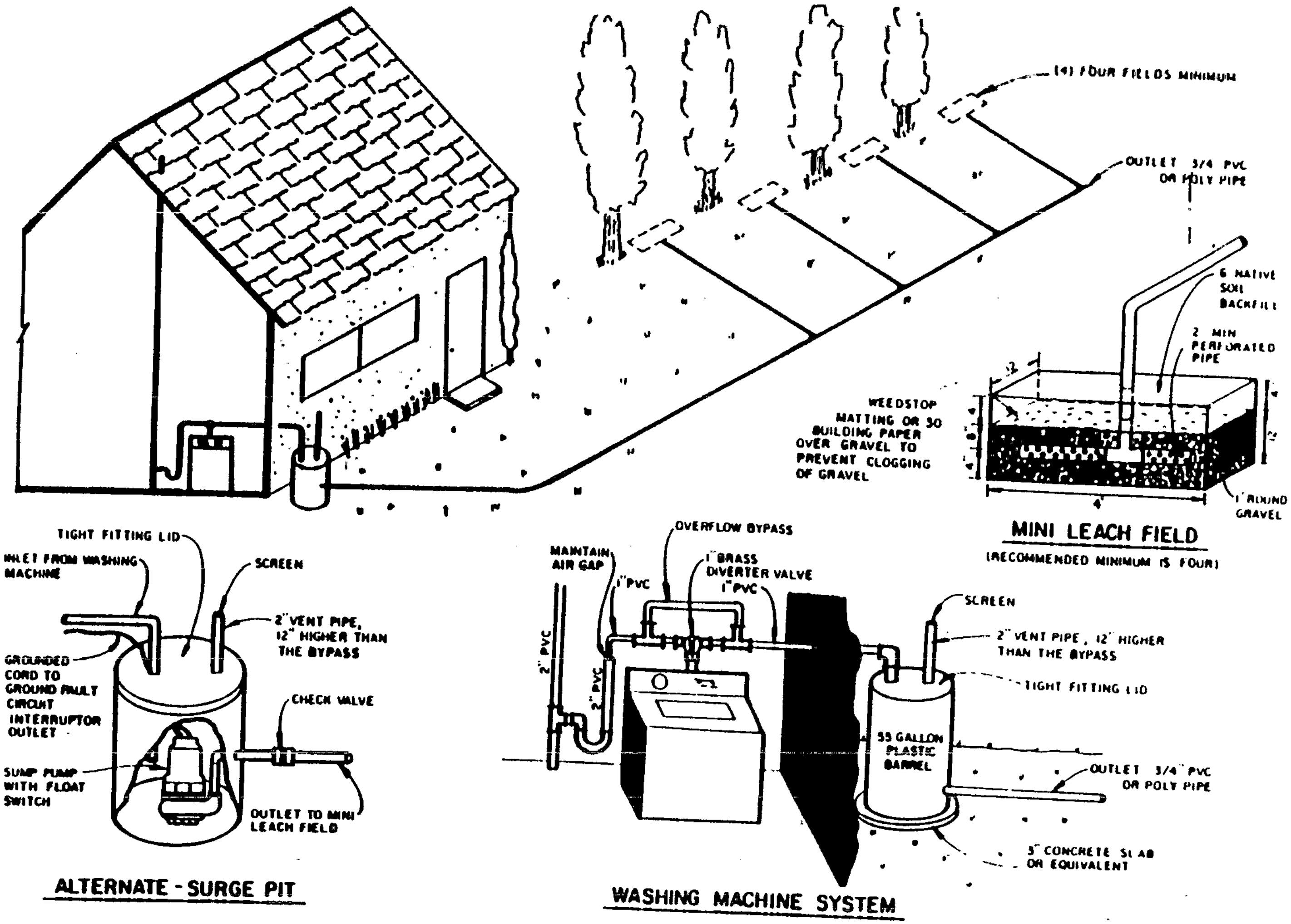


Figure 3-6: System Approved By City of Santa Barbara
Source: Reference #31

Drip Irrigation

Although the mini-leachfield design is the currently approved method in states and counties where on-site graywater recycling is approved for landscape irrigation, the subsurface drip irrigation method also is used. However, compatibility of graywater and subsurface drip technology is unknown. Recognizing this, the Ad-Hoc Graywater Committee in California is undertaking a multi-year study of their technology under real world conditions. A work plan for this study is included in Appendix A.

A typical drip irrigation system is shown in Figure 3-7. The treated effluent pumped from the tank passes through a mesh screen filter, control valve, and a pressure regulator. The header line has a flush valve/vacuum breaker and feeds the driplines. The driplines employ wide passage turbulent flow path/emitters of various types: inline or in-pipe emitters pre-inserted at regular spacings in the pipe for median strips, narrow hedges or lawns; mini-line or button emitters to wrap around trees, plants or individual bushes; and pressure compensating button emitters for pronounced slopes. Driplines typically are buried below ground 4 to 12 inches deep, below cultivation depth. The ends of the driplines can be connected together at the end to facilitate flushing. An automatic flushing valve/vacuum breaker is placed at the end of the lines. The vacuum breaker/flush valves are placed in a gravel-filled valve box below ground. To control several irrigation sectors, an irrigation timer or an alternating valve is sometimes used.

A major concern and problem with drip irrigation has always been the risk of clogging of emitters, even when using fresh water. Roots seeking moisture and nutrients have been known to enter drip irrigation lines and block them in the same manner as they enter sewer pipes.

To minimize this problem, emitters are currently available that use turbulent flow long path design. These emitters operate at a flow rate of 1 to 2 GPH with 0.06 to 0.07 inch orifices. The emitters usually are made out of polypropylene and are resistent to most acids and substances likely to be found in domestic wastewater.

CURRENTLY AVAILABLE TECHNOLOGIES

Many types of graywater systems currently are available in the marketplace. A brief discussion of each known system, including system description, application, testing status, cost, and maintenance, is provided at the end of this section.

CURRENT AND POTENTIAL APPLICATIONS

Graywater recycling is an important demand-side management strategy. It can result in significant water savings in all types of buildings. In a typical residence, it can displace 50 percent of the current use of potable water. Although the issue of water conservation is pertinent world-wide, it is receiving increasing attention in the United States in areas where the prospect of water shortages is most imminent.

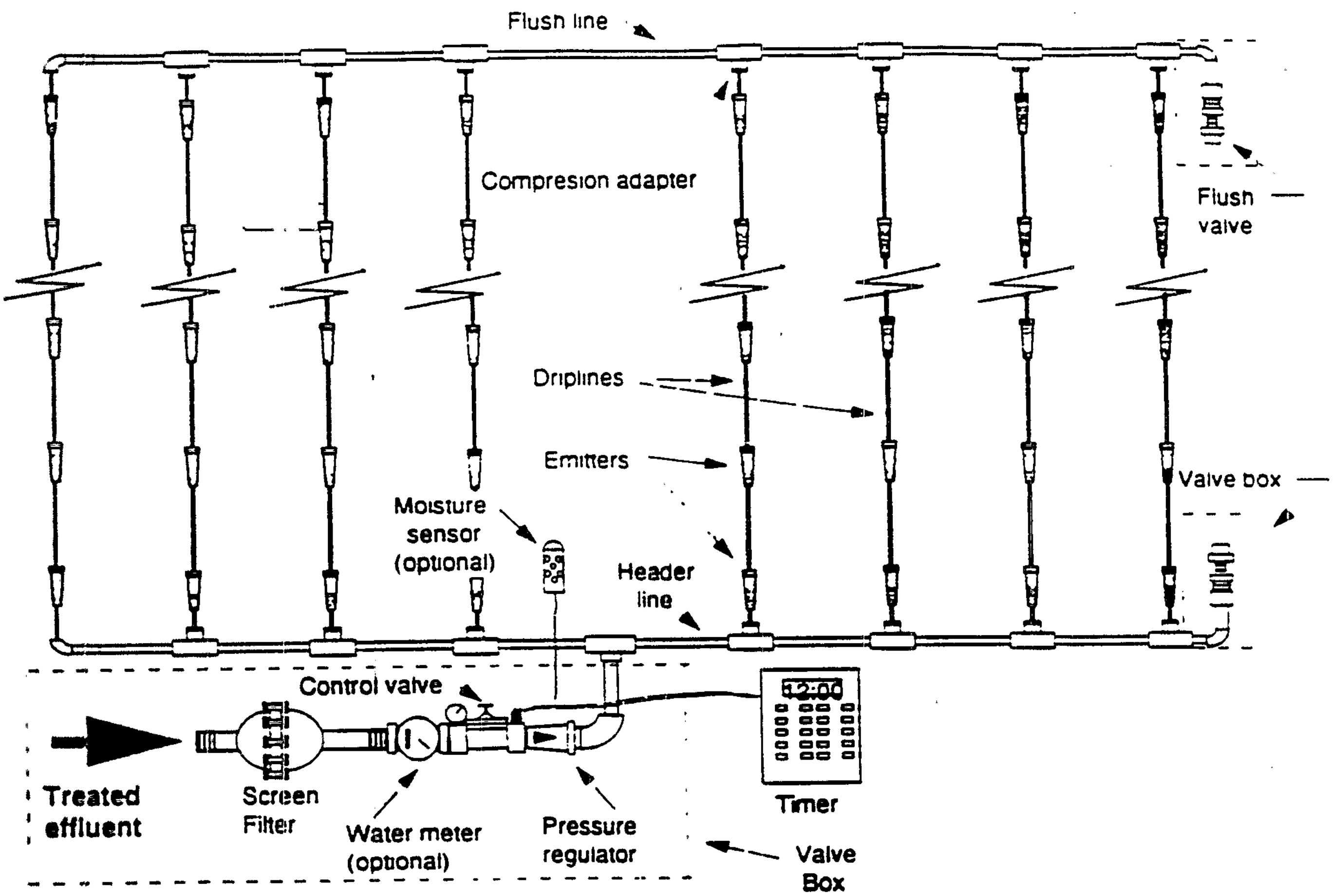


Figure 3-7: Sub-surface Drip Irrigation System
Source: Reference #32

Graywater recycling applications currently can be found in several states, including California, Arizona, and South Dakota. Most of these applications have been in residences in both urban and rural communities experiencing persistent drought conditions. The potential market for graywater recycling is, however, not limited to the above mentioned states. In addition to these states, on-site graywater recycling systems represent a water conservation and peak reduction strategy in other states or regions having arid or semi-arid climates (*e.g.*, Nevada, New Mexico, and portions of Colorado, Washington, Oregon, Texas, Kansas, Idaho, Montana, Nebraska, North Dakota, Utah, and Wyoming). Coastal areas in other states experiencing water shortages (*e.g.*, North Carolina, Massachusetts, South Carolina, and Florida) are also potential markets for graywater systems, as are all of the other major urban areas in the country where sewage treatment plants are already overloaded and expansion possibilities are constrained due to limited availability of funds.

Because graywater recycling can help reduce peak demand, conserve municipal water supplies and delay capital expenditures for expansion of municipal potable water treatment and distribution systems, they could be an element of wastewater plans in every state, city, and municipality. Even though there currently are only a few

CASE IN POINT
HOTEL ESTIMATES $10,000/YEAR SAVINGS WITH GRAYWATER RECYCLING SYSTEM

The Apple Farm Inn & Restaurant in San Luis Obispo, California expects to lower its water bill and sewer bill by about $5,000 per year each with the installation of a graywater recycling system. Payback is expected in 1.5 to 2 years. The 7-room luxury hotel has two 50-pound commercial laundry washers. Each washer is cycled about 14 times per day. Each cycle generates approximately 150 gallons of discharged water. A total of 4,200 gallons of discharged water is generated by both washers. Since all laundry is bleached by the automatic injection of 100 PPM of chlorine, the resulting discharged water is totally free of bacteria. The water is quite clear, but lint and suds are suspended on the surface. The hotel's adjacent free standing, 250-seat restaurant has six pressure-flush toilets in the public restrooms and two tank-type toilets in the employee restrooms.

The graywater recycling system collects and treats the discharged laundry water for reuse for toilet flushing in the public and employee restrooms. It consists of PVC piping, surge tank, pump, two filter media, and chlorinator. The hotel's laundry machines are connected to a 75-gallon surge tank on the floor adjacent to the machines by 3" gravity-fed drains. The discharged water is filtered immediately through two pair of panty hose which are attached to the drain line. A transfer pump is mounted on top of the tank and is controlled by a float switch. This pump transfers the water through a 2 1/2" PVC line approximately 300 feet to a 1,250-gallon plastic storage tank where another panty hose filter is attached. A siphon connects the first 1,250-gallon tank to a second tank. A 100 micron filter bag is attached to the outflow side of the siphon. A multi-stage Jacuzzi well pump is located in the second tank which pressurizes 2 85 gallon bladder tanks located on the roof above the restrooms. A standard tablet-type spa chlorinator is attached to the top of the first storage tank with a supply incoming from the pressurized side of the system. The flow can be adjusted to result in the 1 PPM residual chlorine required by the County Health Department in the final supply line to the toilets. A test valve was required for convenient periodic testing. The second tank has a potable water supply connected to the top of the tank with a double diameter air cap. This supply is controlled by a float valve to add water when demand exceeds supply.

The water in the toilet bowls is indistinguishable from potable water. When flushed, residual detergent causes mild foaming, but the foam dissipates shortly after completion of the cycle. Warning signs required by the local health department were placed over each fixture. They also included a brief explanation of the system and the amount of water being saved.

This system has been well-received at the hotel. Management has received some extremely positive comments about the system and no complaints to date. The system requires very little maintenance. This includes a periodic backwashing of the system, replacement of the filter media, and replacement of the chlorine tablets.

applications of graywater recycling systems nationwide, this could change in the future, due to persistent potable water shortages, overloaded sewage treatment facilities, and strict environmental regulations for water use and disposal.

APPLICATION CONSIDERATIONS FOR IRRIGATION

Because of the nature of graywater, the unsafe, indiscriminate application of graywater can be hazardous. Graywater should not be placed on anything eaten or allowed to collect on the surface of the ground or run off the property. Several factors must be considered in applying a graywater recycling system for irrigation purposes. These factors include: *graywater irrigation needs and production capacity, soil absorption capacity and criteria, graywater salinity and make-up water use, system location, wastewater heat recovery*, and *dual wastewater piping requirements*. Each factor is described briefly below.

Graywater Irrigation Needs and Production Capacity

For irrigation purposes, it is important to determine which trees, shrubs, and plants are to be irrigated with graywater. While many plants are suitable for subsurface irrigation using graywater, certain shade-loving, acid-loving plants are not. Table 3-2 lists the plants suitable and not suitable for graywater irrigation.

Table 3-2: Plants Suitable and Not Suitable for Graywater Irrigation

Suitable	Not Suitable	
• Ornamental trees and shrubs	• Rhododendrons	• Impatiens
• Most flowers and other ornamental ground cover	• Bleeding Hearts (Dicentra)	• Hydrangeas
• Lawns	• Oxalis (Wood Sorrel)	• Camellias
• Fruit trees	• Primroses	• Ferns
	• Philodendrons	• Foxgloves
	• Azeleas	• Gardenias
	• Violets	• Begonias

Source: Reference #24 and #25

The total weekly water requirements typically are estimated using the following rules of thumb:

- Mature fruit tree = 75 gallons/week
- Shade trees (pines, *etc.*) = 50 gallons/week
- Large shrubs = 10 gallons/week

General criteria used for estimating the weekly graywater production in a residence is as follows:

- Determine gallons per minute by showerhead flow and multiply by the showering time per person.

- Add 20 gallons for each bath taken in place of a shower.
- Add 14 gallons to the weekly total for each sink in the system.
- Add 20 gallons per load clothes washing machines times number of loads per week.

The total amount of graywater production (in gallons) then can be figured.

For graywater production in commercial buildings, estimates can be developed using data provided for fixture flows in the standard plumbing code.

Soil Absorption Capacity and Criteria

To avoid water surfacing in difficult soils, the effluent loading rate should be set according to the type of soil. Some localities require that the soil in which the irrigation distribution system is to be placed in must meet certain criteria. For example, Table 3-3 lists design criteria for six typical soils as required by the Water Conservation Office of the California Department of Water Resources.

Table 3-3: Design Criteria of Six Typical Soil

Type of Soil	Minimum ft_2 of leaching/irrigation area per 100 gallons of estimated graywater discharge per day	Maximum absorption capacity gals. per ft^2 of leaching/irrigation area for a 24-hour period
Coarse sand or gravel	20	5
Find sand	25	4
Sandy loam	40	2.5
Sandy clay	60	1.66
Clay with considerable sand or gravel	90	1.10
Clay with small amount of sand or gravel	120	0.83

Source: Reference #18

Graywater Salinity and Make-up Water Use

One of the limitations in the use of graywater for irrigation is the high salinity content usually present in graywater. In particular, water that has been softened and the use of detergents tends to raise the sodium content of the water and consequently makes it less desirable for irrigation. A high sodium content also tends to "seal" the soil.

It is important to check the types of plants that are being irrigated to see if any are more or less tolerant to irrigation with higher salinity water when designing the system. If there is a deficit in the amount of graywater produced or higher salinity levels are a problem, fresh make-up water can be added to dilute the salinity prior to irrigation.

System Location

Some cities and counties which allow graywater systems for irrigation purposes require that certain minimum distances be kept between certain graywater system components and buildings, streams, *etc.* Table 3-4 indicates recommended minimum distances for graywater system components locations as required by San Luis Obispo County in California.

Table 3-4: Recommended Minimum Distance for Graywater System Location[1]

Minimum Horizontal Distance (ft) in Clear Required From:	Surge Tank	Irrigation Field
Buildings or structures[2]	0 ft[3]	2 ft[4]
Property line adjoining private property	5	5
Water supply wells[5]	50	100
Streams and lakes[5]	50	50[6]
Seepage pits and cesspools	5	5
Disposal field & 100% expansion area	5	4[7]
Septic tank	0	5
On-site domestic water service line	5	5
Pressure public water main	10	10[8]

[1]When irrigation fields are installed in sloping ground, the minimum horizontal distance between any part of the distribution system and ground surface shall be 15 feet.
[2]Including porches and steps, whether covered or uncovered, breezeways, roofed patios, car ports, covered walks, covered driveways, and similar structures.
[3]Underground tanks shall be 5 feet from structures.
[4]Assume 45 degree angle.
[5]Where special hazards are involved, the distance also shall be increased as may be directed by the Administrative Authority.
[6]There minimum clear horizontal distances also shall apply between irrigation field and the ocean mean higher tide line.
[7]Plus two feet for each additional foot of depth in excess of one foot below the bottom of the drain line.
[8]For parallel construction/for crossings, approval by the Administrative Authority shall be required.
Source: Reference #18

Wastewater Heat Recovery

Because a graywater recycling system collects used wastewater in a separate piping system, it is possible to extract waste heat from the graywater. For example, graywater from clothes washing machines is very warm. Heat exchange elements can be installed in the graywater system piping to recover the heat that otherwise would be lost. Plate-type heat exchangers have good heat transfer characteristics, but foul quickly. Steel and tube heat exchangers may have a problem with clogging when dirty water is in the tubes. Roll-away shell-type heat exchangers are specifically designed for this type of service and can be easily cleaned. Recovered heat can be used to preheat water in domestic water heaters (Figure 3-8) or for heating hot water systems. Heat recovery can reduce overall building energy consumption, as well as operating costs. Another example of wastewater heat recovery is shown in Figure 3-9. In this application involving graywater from a commercial laundry facility, heat is recovered through heat exchangers for preheating hot water for the clothes washers and domestic water before reusing graywater in urinals and toilets.

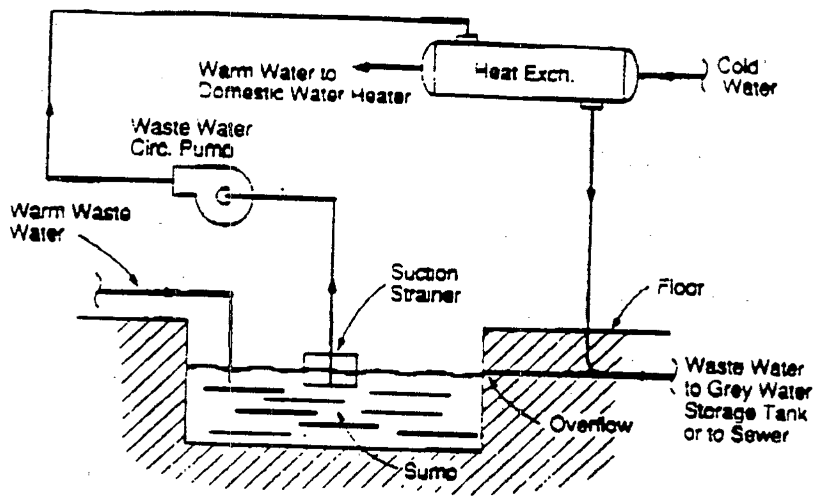


Figure 3-8: Wastewater Heat Recovery
Source: Reference #33

Dual Wastewater Piping Requirements

Graywater recycling systems require the use of dual wastewater piping systems (Figure 3-10). Although new buildings can easily employ dual plumbing systems at very little extra cost, plumbing modifications may be cost prohibitive and difficult to make in a retrofit situation. In such cases, however, it may be more cost effective to direct graywater to a single source such as an ornamental pond or a cooling tower. In all cases, however, the system should be designed so that their is no potential for cross contamination of the potable water supply. The recycled graywater piping should be color-coded and use different materials of construction (*e.g.*, PVC) as approved by local building codes.

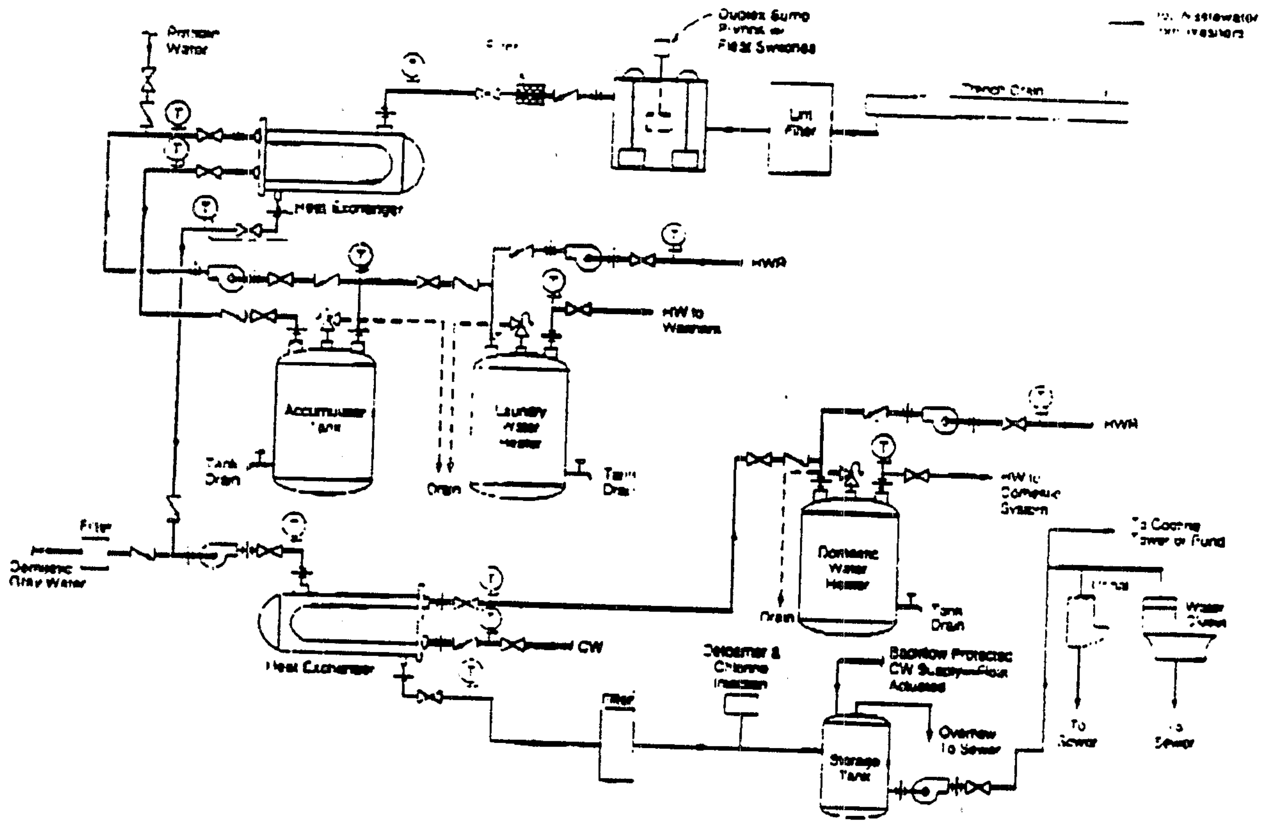


Figure 3-9: Waste Heat Recovery System for Commercial Laundry Facility
Source: Reference #33

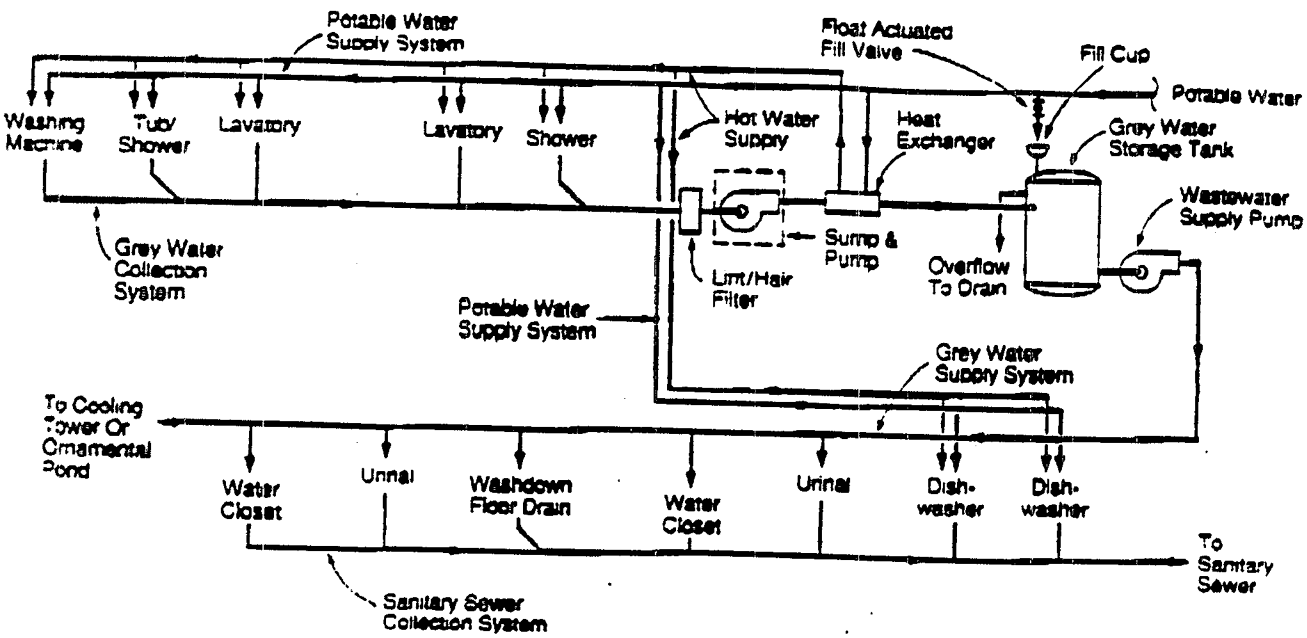


Figure 3-10: Graywater Dual Piping Systems
Source: Reference #33

INSTALLATION CONSIDERATIONS

Graywater systems must be installed in accordance with local plumbing codes. They should be installed by professional licensed plumbing contractors, who are familiar with currently available technologies, the local plumbing codes, and requirements of the local health departments.

The installation of a graywater system requires the retrofitting of existing plumbing. Any modifications or alternations of a plumbing system must be approved by local building departments. Appropriate number of copies of the plot plan indicating the location(s) of the fixture(s) to be included in the system and the area(s) of graywater distribution must be submitted to the local agency along with a completed application to the community development department.

All counties and cities where graywater recycling is currently permitted require their building inspectors to inspect sites and, after the installation, to assume compliance and proper operation.

Code authorities may require a method of distinguishing the potable (drinking) water and the graywater supply systems. These methods may include extensive labelling of the system and/or use of different piping materials, such as copper type "l" for the potable system and PVC for the graywater system. If PVC is utilized for graywater supply piping, flow velocity should not exceed six feet per second because of sound problems inherent with PVC. All graywater outlets must be provided with signage stating that the outlets dispense non-potable water. Proper separation, using reduced pressure backflow preventers, must be provided between potable water and graywater supply systems. Codes also may require injecting a biodegradable dye for easy discrimination between two systems.

OPERATION AND MAINTENANCE CONSIDERATIONS

As discussed in Section II, graywater may carry varying concentrations of potentially disease-causing organisms. However, with proper care and treatment, graywater can be used safely. The primary health risk concern is that pathogenic organisms in the graywater might come into human or animal contact and thereby spread disease. This risk can be significantly reduced by following either of two approaches.

One approach is to limit the level of pathogens in graywater by adequate treatment or by avoiding water containing any fecal matter (*e.g.*, from the toilet or from washing soiled diapers) from being mixed with the graywater system.

The other approach is to prevent human and animal exposure to the graywater. This can be accomplished by not collecting or storing graywater in an open container and by not applying it through a spraying device. Vegetable gardens, lawns, and any other surfaces that humans and animals may come into contact with should not be irrigated with graywater. Mini-leachfield of drip-irrigation systems can be installed to irrigate shrubs, mature fruit trees, and groundcover.

A variety of soaps and cleaning products contain chemical that may be toxic to plants, people; they must not be used in conjunction with a graywater recycling system. For example, powdered detergents and soaps may contain sodium compounds which can build-up in the soil. Excess sodium levels can interfere in the soil's ability to absorb water and can directly damage plants. Soaps and cleaners that can damage plants include detergents that contain boron, borax, chlorine, peroxygen, sodium perborate, petroleum distillates, alkylbenene, sodium trypochlorite, bleaches, or softeners.

Labels on soap and cleaner containers generally do not provide any information as to their plant poisoning and soil damaging contents. However, George Brookbank, a researcher at the Extension Garden Center of the University of Arizona, published his analysis of the chemical composition of many commercial detergents for sodium, boron, and phosphate content, as well as their conductivity and alkalinity levels. Table 3-5 summarizes the results of the analysis.

Still, some soaps that can be used safely with graywater systems are commercially available. Several manufacturers have developed biocompatible cleaners which are specially designed and tested for improved plant irrigation. These cleaners biodegrade into plant nutrients. They contain no sodium, chlorine, or boron and do not adversely affect soil pH or structure.

Rain or excessive irrigation can saturate the soil above the distribution system and cause graywater to pool on the surface. Turning the graywater system off and diverting the graywater to the sanitary sewer line during "rainy" periods can avoid problem pooling from occurring.

Graywater systems require regular maintenance. Some common maintenance procedures are: inspecting the system for leaks and blockages; bimonthly cleaning and replacement of the filter, replacement of the disinfectant, ensuring proper operation of controls; and periodic flushing of the entire system.

POTENTIAL IMPACTS OF GRAYWATER USE ON THE SEWER SYSTEM

Some individuals are concerned that the combined use of graywater and ultra-low flow flush toilets in buildings could lead to accumulation of sediment in sewer pipes, where slopes are minimal. No evidence was found in the literature reviewed for this report that corroborated this fact. Nonetheless, the potential should be studied under controlled pilot projects.

There also is a concern that decreased flows to sewage treatment facilities would reduce the amount of effluent discharged from the sewage treatment plant and increase the concentration of pollutants present in that effluent (34). However, several researchers (34) believe that a gradual, continuous reduction in sewage flow, due to increased graywater recycling for instance, would actually benefit the environment receiving sewage plant effluent discharges. These researchers also indicate that

Table 3-5: Chemical Composition of Several Commercial Detergents

Detergent	Sodium	Conductivity (micro mhos/cm)	Alkalinity (as ca co_3mg.1)	Boron (mg/1)	Phosphate (mg/1)
Ivory Flakes	5.0	66	39	.0053	.96
Breeze	16.7	327	39	.0775	20.0
Cheer	22.5	359	43	.035	23.6
Poderosa (Mexico)	20.0	397	39	.05	12.0
Ariel (Mexico)	23.2	423	60	less than .012	26.8
Bold	19.0	352	43	.0275	13.2
Cold Power	18.4	402	100	.06	27.2
Perform	12.75	464	104	.03	8.4
Salvo	18.0	464	77	.02	52.4
Fab	19.25	495	60	.07	32.0
All	23.4	555	81	.49	36.4
Dash	36.0	763	83	.0175	46.8
Downey Fabric Softener	3.5	22.7	70	less than .012	.4

Source: Reference #34

malfunctioning of wastewater treatment systems can be avoided and substantial savings in costs of water supply and wastewater treatment can be anticipated by preplanned water conservation programs as a result of increased use of graywater.

Clearstream Wastewater System
Clearstream Wastewater Systems, Inc.
P.O. Box 705, Silsbee, Texas 77656
Jerry McKinney
409-385-1395

SYSTEM DESCRIPTION

Clearstream Wastewater Systems manufactures a wastewater treatment unit which through aeration and clarification provides an environment for aerobic bacteria and other microorganisms that converts incoming wastewater into reusable water. It can be used separately (Figure 3-11) or in combination with a septic tank (typically 300-500 gallons) which provides for anaerobic primary treatment (Figure 3-12).

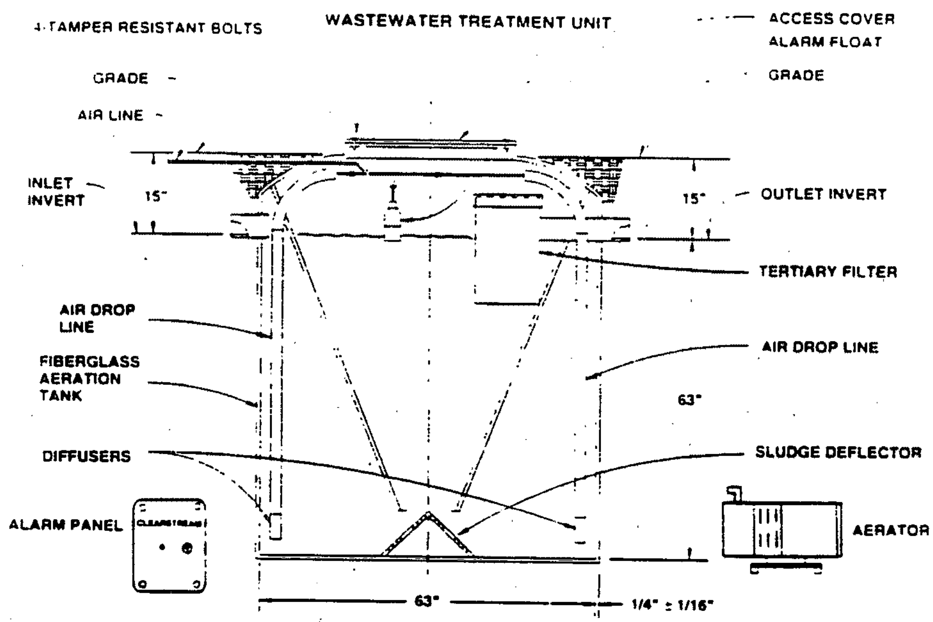


Figure 3-11: Clearstream Wastewater Treatment System

APPLICATION

The Clearstream Wastewater System is currently being used in a few single-family residences located in Texas, Louisiana, Georgia, and Florida. Typical use of the treated graywater is for spray or drip irrigation of lawns, pastures, landscape beds, and golf courses. With additional accessories, the effluent can be used for several other non-potable water applications.

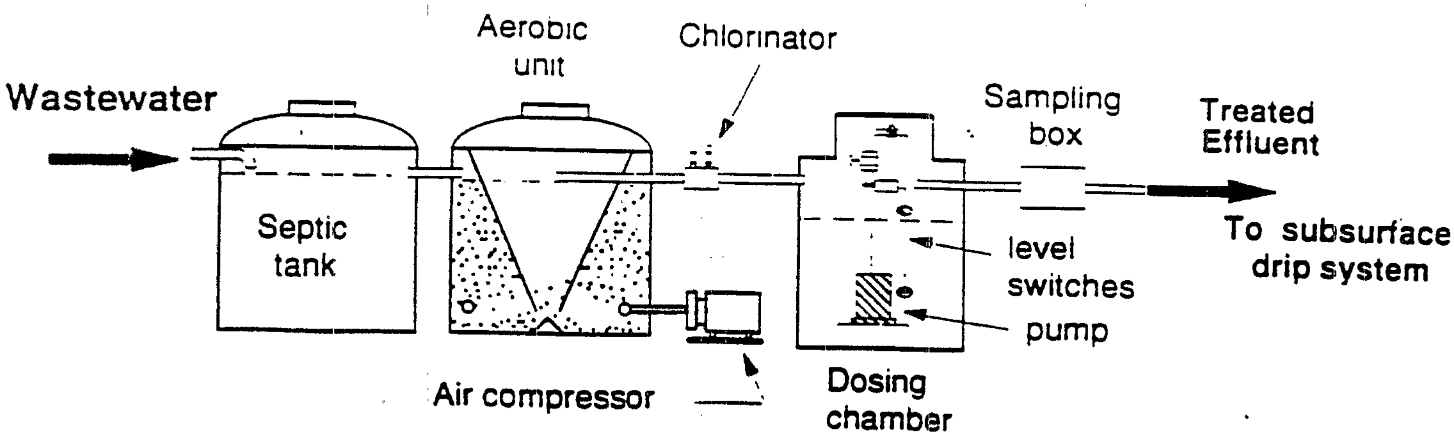


Figure 3-12: Clearstream Wastewater Treatment System with Septic Tank

TESTING STATUS

This system has been tested by the National Sanitary Foundation and has been given NSF Class 1 approval.

COST

The installed cost of this system (including drip irrigation) typically ranges from $4,000 to $5,000.

MAINTENANCE

The manufacturer of this system states that the following periodic maintenance will be required.

- Repair or replacement of the aerator (2 to 10 years)
- Cleaning of filters on aerator (6 mos. to 2 years)
- Breaking up scum in clarifier (6 mos. to 2 years)
- Pumping sludge from aeration tank (2 to 5 years)
- Pumping sludge from trash trap (2 to 5 years)
- Checking aeration diffusers (annually)
- Back washing tertiary filter (annually)

The Grey Water Recycler
King O'Lawn
P.O. Box 1068
10127 Adell Avenue
Southgate, California 90280
Thomas Kristy

SYSTEM DESCRIPTION

This system consists of a polyeurethane tank (120-gallon capacity), bacteria control system, and water filter. It connects to the discharge line from the clothes washer where it filters and sanitizes incoming water, then deposits it into the holding tank. When the tank is full, excess graywater is sent down the drain. A garden hose connected at the base of the tank can be used for applying water to the landscape.

APPLICATION

The system currently is being marketed for single-family residential applications.

TESTING STATUS

This system is one of eight systems currently being tested by the City of Los Angeles. Otherwise, no testing has been performed to date.

COST

The installed cost of this system is about $800.

MAINTENANCE

Although no maintenance requirements were provided with information from the distributor, standard cleaning and repair/replacement practices should apply.

Water Recycler

Ken Leek
1973 Cordilleras Road
Redwood City, California 94062
Ken Leek
415-369-7010

SYSTEM DESCRIPTION

In this system, graywater is first passed through a wire mesh particulate filter, then passed through a thermostatically-controlled electric heater which raises water temperature to 90F. Next, the water passes through a sediment filter, carbon filter, color filter and is treated by ultraviolet irradiation, before it is collected in the storage tank. The water is pumped to landscape irrigation system.

APPLICATION

The primary application of this system is residential. Because the system is very new to the marketplace, there are no installations on customer premises. However, the developer of the system has an installation of a prototype in his home that reclaims graywater from a clothes washing machine.

TESTING STATUS

The developer plans on having the Water Recycler tested and certified by the National Sanitation Foundation. Sequoia Analytical in Redwood City has performed some initial bacteriological and chemical analyses of graywater samples taken from the developer's own home.

COST

The installed cost currently is estimated to be $2,900. However, the cost is likely to decrease to about $1,000 if demand for Water Recycler increases significantly.

MAINTENANCE

Although no maintenance requirements were provided with information from the distributor, standard cleaning and repair/replacement practices should apply.

Automatic Grey Water Apparatus
AGWA Systems, Inc.

801 South Flower Street
Burbank, California 91502
Gary J. Stewart
800-GREY-H20

SYSTEM DESCRIPTION

This system uses a dual tank system consisting of a gravity-fed tank where graywater drains and a storage tank where water is stored. It requires an electronic controller that constantly monitors the system and allows it to work in unison with the customer's existing irrigation system. Electronics also allow a special sand filter specifically designed for this system to backwash daily, weekly, or monthly depending upon the amount of use the system gets.

APPLICATION

The current application of this system is residential. However, it can be used in small commercial buildings.

TESTING STATUS

This system is one of eight systems currently being tested by the City of Los Angeles. Otherwise, no other testing has been performed to date.

COST

The installed cost for a two bathroom residence is about $3,200. Because this system is very new to the marketplace, it is not known how long the sand in the filter will last under various conditions. However, it is contemplated that a service contract involving periodic testing of the system and a new canister of sand will cost about $75.

MAINTENANCE

System maintenance includes: changing of the filter bag (costs approximately $40), turning of the irrigation valves, and manually flushing the subsurface irrigation system (if the system uses subsurface drip irrigation, it needs to be flushed every six months).

Cycle H_2O
Homestead Utilities
HC62, Box 3812
Camp Verde, Arizona 86322
Anton Van Puffelan
800-292-5340

SYSTEM DESCRIPTION

This system recovers graywater from tubs, showers, and clothes washing machines and passes it through a filter to a tank. The graywater from the tank then is pumped to the toilet tank or flushing where it used instead of potable water.

APPLICATION

This system currently is being used in rural residences in Arizona.

TESTING STATUS

No testing has been performed to date.

COST

The installed cost of this system in a new residence is about $500, whereas in an existing residence where plumbing modifications must be made it is about $800.

MAINTENANCE

The distributor recommends chlorine bleach and one cup of white vinegar be added periodically to dissipate soapy residue in the system.

Fluid Systems
Ted Adams
2800 Painted Cove Road
Santa Barbara, CA 93105
Ted Adams
805-964-1211

SYSTEM DESCRIPTION

This system (Figure 3-13) passes graywater through a polyester fiber filter, and then deposits it in a tank. A pump distributes the graywater to an approved distribution system. An overflow pipe discharges excess graywater.

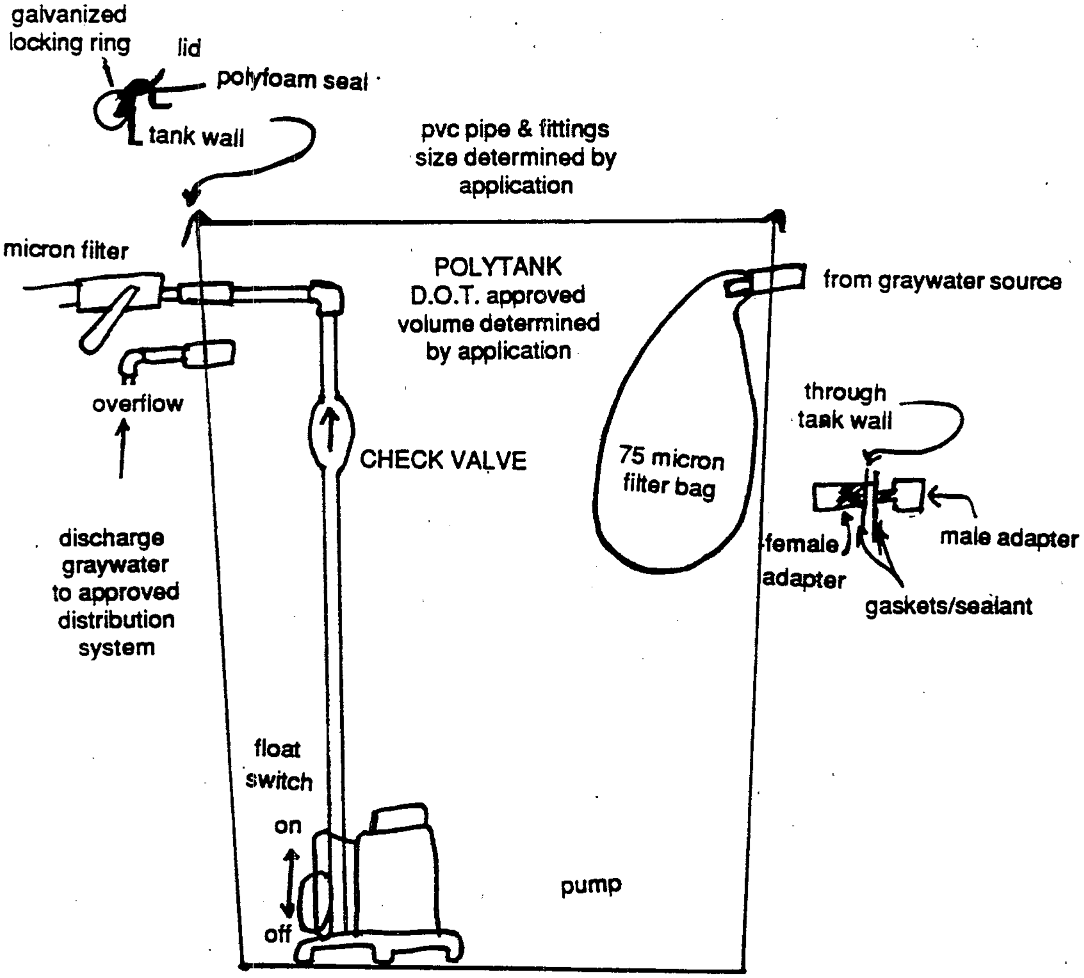


Figure 3-13: Fluid Systems' Graywater System

APPLICATION

This system currently being applied in the residential sector.

TESTING STATUS

No testing has been performed to date.

COST

The installed cost of this system in a new residence is about $800.

MAINTENANCE

Depending on the system use, the polyester filter requires periodic cleaning/replacement and the system requires flushing at least once a month.

Aquabank
Graywater Management
85097 Territorial Highway
Eugene, OR 97402
Tim Pope
503-687-0601

SYSTEM DESCRIPTION

This system currently is under development. It will use a 300 to 800 gallon tank with a sand/gravel filter that will be backwashed every 6-8 hours. All controls will be automatic. It will also utilize ozone treatment.

APPLICATION

The current application of this system is residential.

TESTING STATUS

No testing has been performed to date.

COST

The purchase cost of the system is $3,000. Installed cost is site-dependent, but will be about $3,500.

MAINTENANCE

Although no maintenance requirements were provided with information from the distributor, standard cleaning and repair/replacement practices should apply.

HYDROX Grey Water Treatment System

The Watergroup, Inc.
681 Gatewood Lane
Sierra Madse, California 91024
Dale Sodlick
818-355-2623

SYSTEM DESCRIPTION

This system is capable of treating graywater from a septic tank for irrigation of lawns, washing walks, *etc.* It uses the trademarked HYDROX system (Figure 3-14) which consists of an optional prefilter, a system pump, a cavitation chamber, and an ultraviolet reactor plus appropriate piping and valves. The system is self-contained and capable of being mounted in a dry well adjacent to the septic tank.

APPLICATION

This system is designed for application in residential and commercial buildings.

TESTING STATUS

No testing has been performed to date.

COST

No HYDROX Grey Water Treatment Systems have been sold as yet. The cost of this system was not disclosed by the distributor.

MAINTENANCE

Except for the pump, this system employs no moving parts. UV lamp replacement is required about every 14 months.

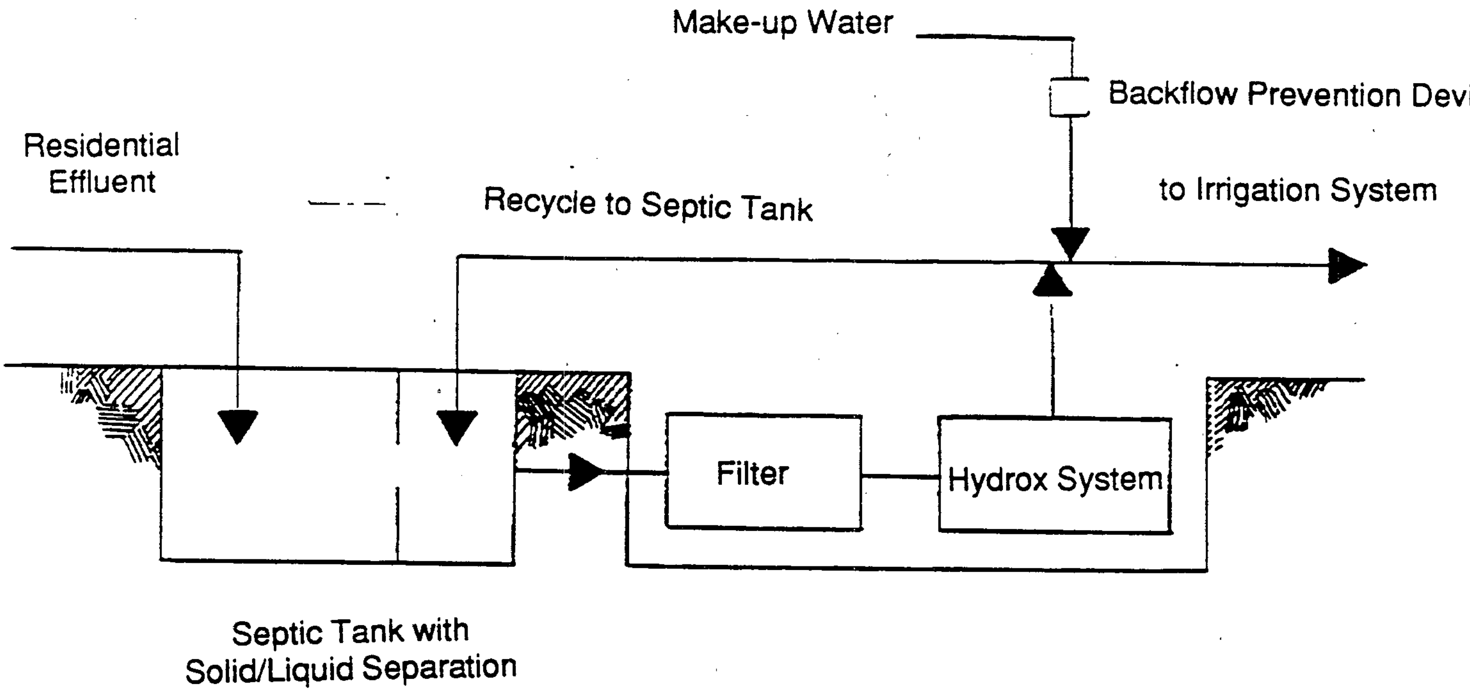


Figure 3-14: Basic Schematic of Hydrox Grey Water Treatment System

Watersave
Watersave
914 Prospect Avenue
Hermosa Beach, California 90254
Wayne Stanton
310-379-3575

SYSTEM DESCRIPTION

This system passes graywater through a filter, and then deposits it into a tank. A pump distributes the graywater to an approved distribution system. An overflow pipe disposes of excess graywater.

APPLICATION

The current application of this system is single-family residential.

TESTING STATUS

No testing has been performed to date.

COST

The installed cost of this system in a new residence is about $800 to $1,500.

MAINTENANCE

Although no maintenance requirements were provided with information from the distributor, standard cleaning and repair/replacement practices should apply.

Grey Water System

Grey Water Systems
438 Addison Avenue
Palo Alto, California 94301
Steve Bilson
415-324-1307

SYSTEM DESCRIPTION

This system passes graywater through a filter, and then deposits it into a tank. A pump distributes the graywater to an approved distribution system. An overflow pipe disposes of excess graywater.

APPLICATION

There have been about 36 installations of this system in residential buildings in San Mateo. They are being considered for application in San Mateo/Santa Barbara Counties.

TESTING STATUS

This system currently is being tested for water quality at the state environmental laboratory.

COST

The installed cost of this system in a new residence is about $900.

MAINTENANCE

The only maintenance required is that the homeowner must change the filter once a month.

AlasCan
AlasCan
Box 278
Healy, Alaska 99743
Clint Elston
907-683-2698

SYSTEM DESCRIPTION

In this system, graywater is passed from bathtubs, showers, clothes washing machines, dishwashers, bathroom sinks, and kitchen sinks into a tank (Figure 3-15). The tank is divided into the influent/preliminary, aeration and settling/effluent chambers to clean the wastewater. The treated graywater may then be pumped to other areas for reuse.

APPLICATION

This system has been designed for residential (single- and multi-family) and commercial (hotels, motels, and small office buildings) applications.

TESTING STATUS

This system has been tested by the University of Alaska.

COST

The installed cost of this system in a new residence is about $3,000.

MAINTENANCE

Although no maintenance requirements were provided with information from the distributor, standard cleaning and repair/replacement practices should apply.

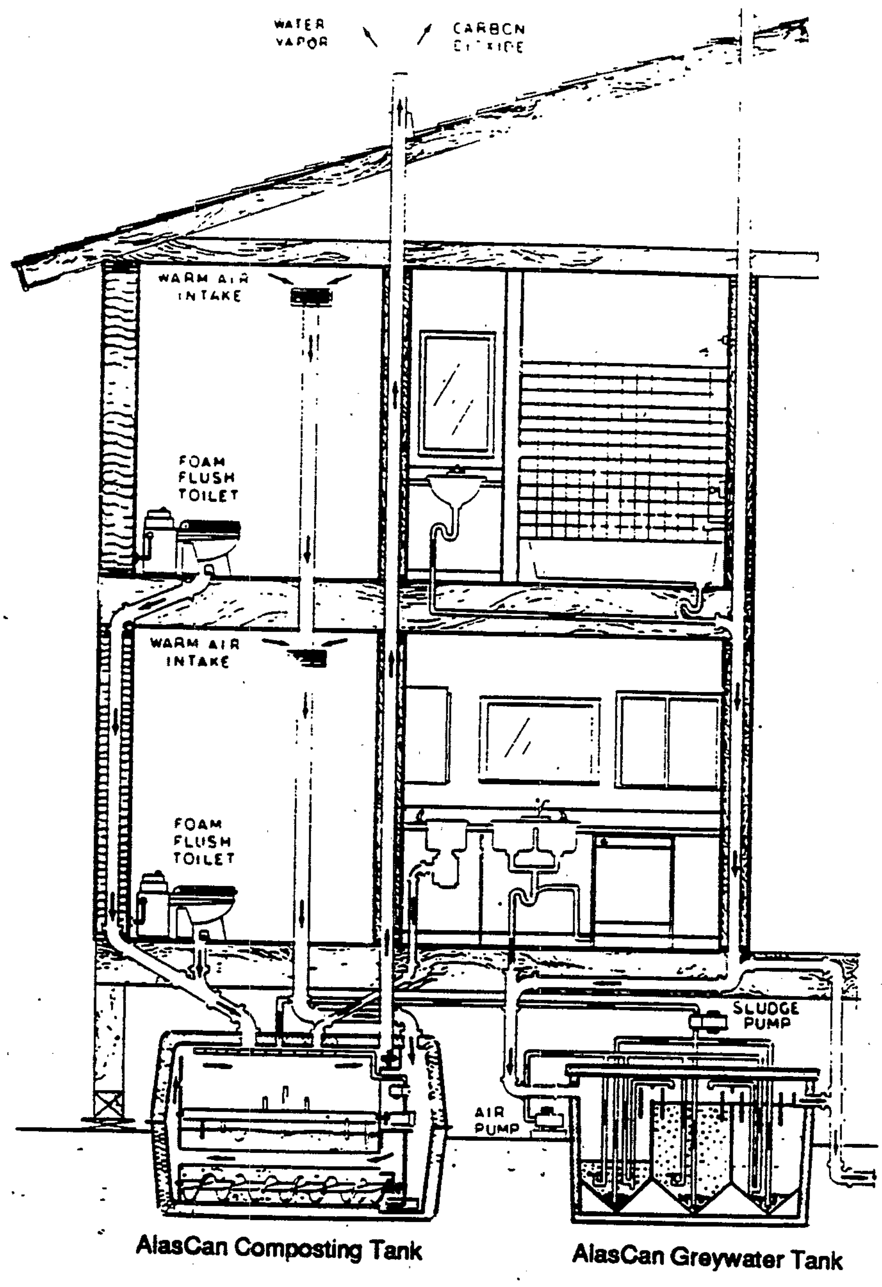


Figure 3-15: AlasCan

Water Maide

Water Maide
Desiderata Ranch
4617 County Road 2
Berthoud, Colorado 80513
Douglas R. Spence
303-772-9611

SYSTEM DESCRIPTION

This system collects the water drained from appliances, sinks and bathtubs (Figure 3-16), then strains and superficially treats the water with a defoaming and deodorizing agent, and returns it for use in toilets. It consists of a tank, a patented internal filtering system, a chemical dispenser, and automated operating controls.

APPLICATION

Approximately 110 units of this system were installed in the mid-1980 in residential buildings. It can be applied in new construction or retrofit of existing buildings.

TESTING STATUS

No testing has been performed to date.

COST

The installed cost for a new system is about $1,000 to $1,100. If multiple units are involved, the installed cost may decrease to $700 to $800.

MAINTENANCE

General maintenance procedures involve opening a gate valve to allow sediment in the Water Maide to exit into the sewer line, replenishing the chemical supply, and rinsing or replacing the standard cartridge filter. These procedures should be performed about one a month for family of four.

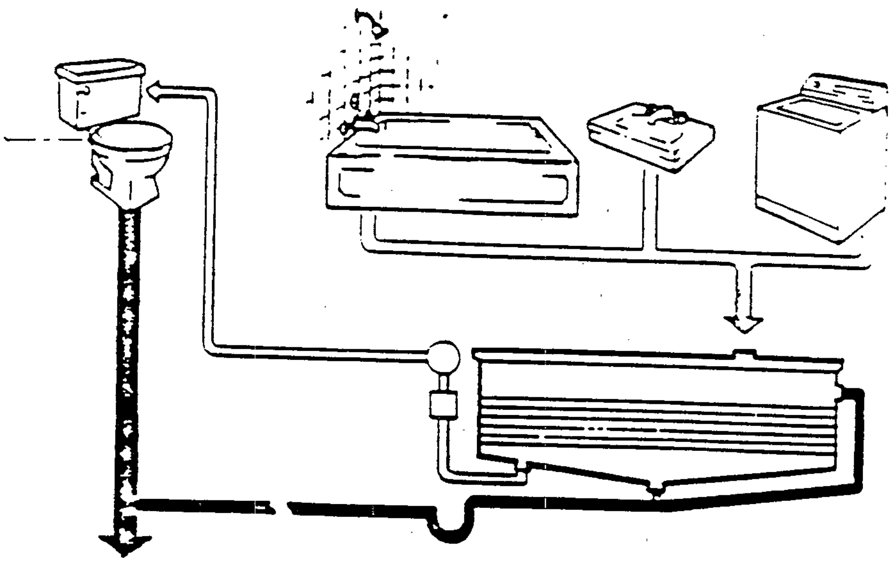


Figure 3-16: Water Maide

Gray Water Recycler

H. & E., Ltd
1555 North King Street
Hampton Virginia 23669
Nakley Anthony Risk
(804) 727-7733

SYSTEM DESCRIPTION

This system collects graywater from the shower/tub. The graywater is passed through two activated carbon filters to remove hair and other pollutants, then distributed to a tank. It is then gravity-fed to the landscape irrigation system.

APPLICATION

No installations of this system have been performed as yet. However, one installation is being considered in New Mexico.

TESTING STATUS

No testing has been performed to date.

COST

The initial cost of this system is about $150. The manufacturer offers leasing for the system at $10 per month including maintenance.

MAINTENANCE

The only maintenance requirement is that the filter must be changed every month.

Cycle-Let Graywater Treatment and Recycling System

Thetford Systems, Inc.
P.O. Box 1285
Ann Arbor, Michigan 48106
John Irwin
800-521-3032

SYSTEM DESCRIPTION

This system uses biological treatment coupled with membrane filters for complete liquid/solid separation. It also involves the use of ultraviolet disinfection. Depending upon the application, this system also could employ activated carbon filtration.

APPLICATION

This system is designed primarily for hotel and motel applications and for use in recreational facilities.

TESTING STATUS

This system has been tested and certified by the National Sanitation Foundation. It meets the requirements of NSF Standard 41 for wastewater recycle/reuse.

COST

The installed cost of this system varies with system size and flow capabilities. It is as follows.

- 350 GPD flow -- $ 70,000
- 4200 GPD flow -- $ 169,000
- 8500 GPD flow -- $ 313,000

This equipment, however, generally is leased to the building owner.

MAINTENANCE

Because the system typically is leased, operation and maintenance service is provided by Thetford Systems, Inc. Annual O&M costs range from $1,000/month the 350 GPD system to $3,750/month for the 8500 GPD system. Cost for electricity needed for equipment operation is borne by the building owner. Annual energy consumption for the three systems is estimated to be as follows.

- 350 GPD flow -- 13,000 kWh/year
- 4200 GPD flow -- 60,000 kWh/year
- 8500 GPD flow -- 95,000 kWh/year

Water Cycle
P.O. Box 1841
Santa Rosa, California 95402
Robert Kourick
707-874-2606

SYSTEM DESCRIPTION

The Water Cycle system recovers graywater from the clothes washing machine, passing it through a cloth filter into a plastic/fiberglass tank. The graywater is distributed to the irrigation system using gravity or a small pump.

APPLICATION

This system currently being applied in the residential sector.

TESTING STATUS

No testing has been performed to date.

COST

The installed cost for a pumped system for a clothes washing machine installation is about $ 500.

MAINTENANCE

Depending on the system use, the cloth filter requires periodic cleaning/replacement and the system requires flushing at least once a month.

Clivus Multrum, Inc.
21 Canal Street
Lawrence, Massachusetts 01840-1801
Carl Lindstrom
(508) 794-1700

SYSTEM DESCRIPTION

A typical graywater system for a residence consists of a stretch filter (Figure 3-17) and a graywater ejector pump. The filter catches the fibers and particles and the pump distributes the graywater to the sub-surface irrigation field.

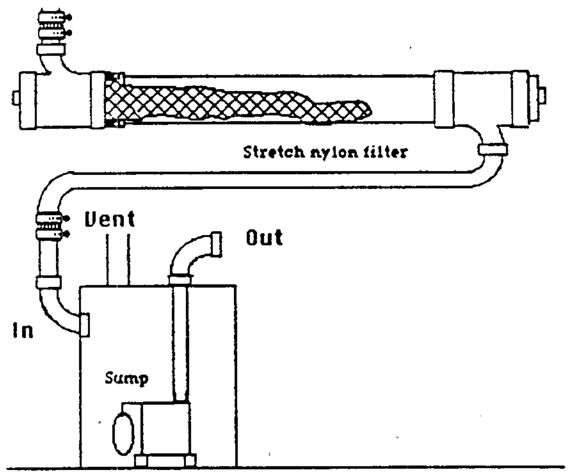


Figure 3-17: Stretch Filter Pretreatment

APPLICATION

This system can be used in residences primarily for sub-surface irrigation purposes.

TESTING STATUS

The system currently is being tested by the University of West Virginia. However, it has not been tested by NSF.

COST

The installed cost of this system is $900.

MAINTENANCE

The stretch filter typically requires replacement about once a year. Maintenance can

IV. COMBINED WASTEWATER TREATMENT AND RECYCLING SYSTEMS

Combined wastewater treatment and recycling systems differ from graywater recycling systems in that they collect and treat the total wastewater (graywater and blackwater). The use of these systems has many significant advantages over conventional wastewater treatment and disposal systems, both from a wastewater management perspective as well as a water use/water conservation perspective. Reuse of on-site wastewater saves limited and dwindling water resources and replaces or reduces the need to develop additional sources of water supply. Although combined wastewater treatment and recycling systems currently are not competitive with on-lot septic tank/leach field and public sewer systems, there are many sites that are otherwise not developable due to site conditions that could be developed with the use of such systems.

This section presents a brief overview of combined wastewater treatment and recycling systems, including discussion of: *combined wastewater uses*; *basic system concepts*; *currently available technologies*; *current and potential applications*; *application considerations*; *installation considerations*; and *operation and maintenance considerations*.

COMBINED WASTEWATER USES

Of the less than 100 combined wastewater treatment and recycling systems currently in use in commercial buildings, most recycle the treated wastewater for toilet and urinal flushing. Other current end-uses of the treated wastewater include landscape irrigation and supply water for ornamental ponds.

BASIC SYSTEM CONCEPTS

The major components of a combined wastewater treatment and recycling system include collection and storage tank(s), piping, filter media, pumps(s), and controls. Depending upon the application involved, controls are usually more complex and, in most cases, microprocessor-based. The treatment methods typically used include *aerobic treatment*, *collection*, *settling and sand filtration*, and *biological treatment with filtration and disinfection*. Each is described briefly below.

Aerobic Treatment

The aerobic system uses an aerobic biological treatment process to oxidize and remove soluble or fine suspended materials which cannot be removed simply by filtration or sedimentation. This system provides compartmentation, hydraulic flows, and oxygen necessary to optimize the aerobic process. No addition of chemicals usually is required.

Collection, Settling and Sand Filtration

This system uses a septic tank to collect the combined wastewater from the building. The wastewater then is pumped to the sand filter to remove suspended materials. It is similar to the system discussed in Section 3.

Biological Treatment with Membrane Filtration, Carbon, and Disinfection

This system uses a treatment process that incorporates biological treatment, membrane filtration, activated carbon, and ultraviolet light or ozone disinfection. Sludge accumulates in a trash trap or in a biological treatment unit. The system typically is housed in the basement of the building it serves or in a separate out-building.

CURRENTLY AVAILABLE TECHNOLOGIES

Combined wastewater treatment and recycling systems are commercially available from only a few companies, some of which also manufacture/distribute graywater systems. A brief discussion of four systems, including system description, application, testing status, cost, and maintenance, is provided at the end of this section.

CURRENT AND POTENTIAL APPLICATIONS

On-site wastewater treatment and recycling system currently are being used in several states, including California, New Jersey, New York, Maryland, Virginia, Indiana, and Michigan. Many of these applications have been in office buildings and complexes and schools. Other building types where such technology can be used include: shopping centers, public recreational facilities, hotels and motels, airports, multifamily residential facilities, industrial plants, and hospitals.

Wastewater treatment and recycling systems have been used in most applications because the area where the building was located could not be served by a public sewer and on-site problems prohibited a large sanitary leachfield. In other instances, they have been used because conventional on-site treatment was a problem as a result of poor soil, high groundwater, wetlands, or concerns for groundwater contamination, or water conservation was an important consideration.

APPLICATION CONSIDERATIONS

Two of the most important factors that must be considered in application of a combined wastewater treatment and recycling system are *wastewater need and production capacity* and *system location*. Each factor is described briefly below.

Wastewater Need and Production

For landscape irrigation, the need is established by using various rules of thumb as discussed in Section 3. For flushing of toilets and urinals, typically 1.5 gallons (for flush units) and 0.5 gallons per flush, respectively are used.

CASE IN POINT
CALIFORNIA MOBILE HOME PARK INSTALLS WASTEWATER TREATMENT SYSTEM FOR SURFACE IRRIGATION

A mobile home community found itself facing state mandates against discharge to surface waters. The mobile home park owners had utilized spray irrigation following wastewater treatment by a conventional "package" treatment plant. However, this plant was not meeting standards due to inefficiency and peak loading problems.

A combined wastewater treatment system was installed in January 1991. The system currently is used for treatment and the effluent is irrigated on a nearby field of non-edible crops.

CASE IN POINT
WASTEWATER TREATMENT & RECYCLING SYSTEM INSTALLATION AT HEADQUARTERS PARK ESTIMATED TO SAVE $15,000 PER YEAR

A office complex near Princeton, New Jersey consists of four separate buildings totaling 366,550 square feet of office space. It is located in a rural area where public sewers are not available. After an initial wastewater treatment plant was rejected, a system that reduced wastewater discharge through recycling of treated effluent for use as flush water in the facility's toilets and urinals was chosen. This system could reduce the wastewater discharge volume by approximately 94%. It could be easily accommodated on-site. A capital cost savings of over $250,000, plus an estimated water use cost savings of $15,000 per year, was achieved,.

For wastewater production in a commercial building, it typically is assumed that a building will support approximately one person for every 200 square feet of gross space. The actual volume of wastewater to be treated is calculated based on the number of daily uses of the toilet and urinal fixtures. It commonly is assumed that 50 percent of the occupants are men and 50 percent are women. Women use a toilet 100 percent of the time and studies have shown that men use the toilet 24 percent of the time and the urinal 76 percent of the time. The total sanitary facility use over an eight hour period is three uses per person per day. In addition, lavatory sink use is estimated at 0.25 gallons per toilet or urinal use. The contribution to flow from urination adds approximately 0.07 gallons per day (gpd) per fixture use.

System Location

The location of system components depends on the type of the system being utilized. Some general guidelines are:

- Installation of tanks, pumps, controls, and piping must allow easy access for service.
- Distances from any building, lot line, or water supply must conform to local health regulations.
- Areas (for irrigation uses) that receive runoff or are highly subject to flooding must be avoided.

INSTALLATION CONSIDERATIONS

Combined wastewater treatment and recycling systems must be installed in accordance with local plumbing codes. They usually are installed by professional, licensed plumbing contractors who are fully familiar with the local codes and requirements of the local health department. The installation may require modifications of the existing plumbing system and code authorities may require a method (*e.g.*, labels or signs) of distinguishing potable water from wastewater.

OPERATION AND MAINTENANCE CONSIDERATIONS

One of the major objections that regulatory agencies have relative to the us of on-site wastewater treatment and recycling systems is the reliability of operation and maintenance. Recognizing this, many manufacturers of these systems have developed sophisticated computerized monitoring and control systems that provide remote monitoring and alarm capability that provides a minute by minute, 24-hour a day surveillance on each system. They also offer (either directly or through authorized distributors) annual service contracts to assure reliable operation of their equipment and controls. Discussions with regulatory agencies and selected users confirms that service contracts which provide routine preventive maintenance and inspection are a preferred method to assure reliable operation rather than provision of periodic emergency response. Furthermore, long term operating costs also can be more effectively controlled when the equipment supplier/manager is made responsible for parts and equipment replacement under a fixed management fee arrangement.

Cycle-Let
Thetford Corporation
P.O. Box 1285
Ann Harbor, Michigan 48106
John Irwin
800-521-3032

SYSTEM DESCRIPTION

Figure 4-1 illustrates a typical Cycle-Let was ewater treatment and recycling system. This system processes wastewater through a series of unit operations producing a highly treated effluent. The treated wastewater is reused as flushwater in toilets and urinals. Any residual effluent not reused for toilet flushing is discharged to a small on-site subsurface disposal field or sanitary sewer. In some applications, the treated wastewater can be used for on-site landscape irrigation.

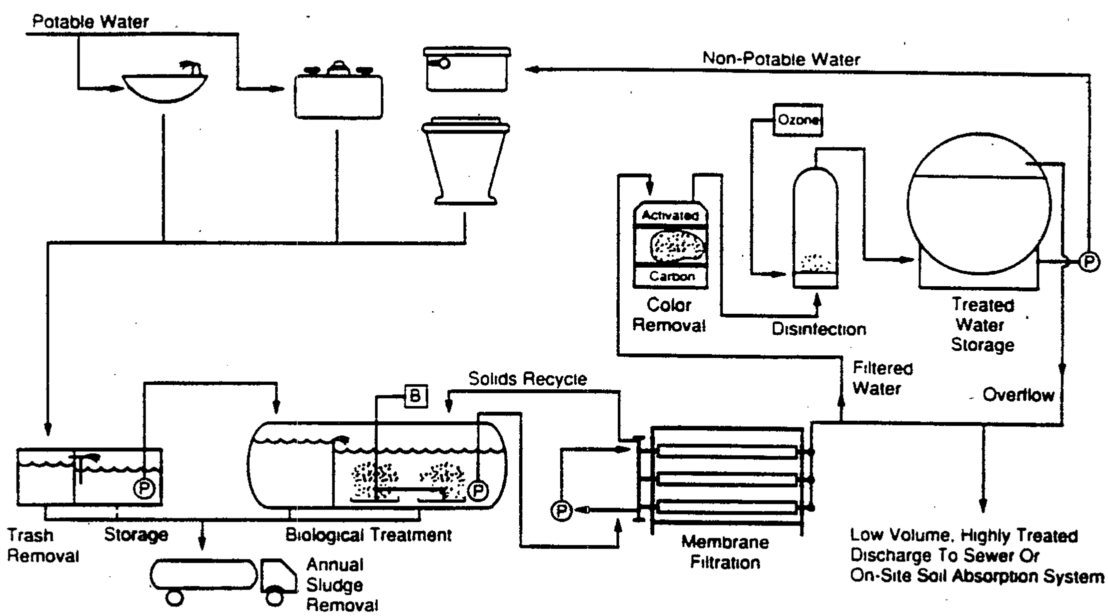


Figure 4-1 : Cycle-Let Wastewater Treatment and Recycling System for Commercial and Industrial Buildings

The treatment process consists of three basic steps: *biological treatment, filtration* and *final polishing and disinfection.* The wastewater is first collected in a buried pre-treatment trash trap/sump tank. The trash chamber provides grit removal and gross solids retention; the sump provides flow equalization and an emergency storage reservoir. After treatment and equalization, the wastewater is pumped to the biological treatment system.

The *biological treatment* system incorporates both anoxic and aerobic processes. The first anoxic stage receives the raw wastewater. Anoxic organisms convert the nitrates to nitrogen gas (denitrification) while consuming BOD. In the second stage, air is supplied through blowers to provide an aerobic environment for nitrification of ammonia, further BOD reduction, and solids digestion. The digestion process reduces solids so efficiently that residual stored solids are removed by hauling only once per year.

Filtration of the biological solids is accomplished with tubular ultrafiltration membranes. These membranes provide consistent and complete removal of suspended solids and microorganisms. The rejected solids are returned to the waste treatment tank for further digestion. The filtered effluent proceeds to the final polishing step, except for a small volume that is discharged.

Once the biological solids have been separated, the wastewater is *polished and disinfected*. In this process the wastewater passes through activated carbon adsorbers. This removes any remaining color and odor and produces a sparkling clear water. Next, the flow is disinfected by ultraviolet radiation or ozone. The reclaimed wastewater is then stored in a treated water reservoir where it will be recycled to flush toilets and urinals.

The process is odor free, requires no chemical additions and can be housed within the facility it serves. Water conserving fixtures such as 1.5 gallon toilets and self-closing lavatory faucets are generally used with the system to improve system economics.

APPLICATIONS

The Cycle-Let system is designed for hotel and motel applications and for use in recreational facilities.

TESTING STATUS

This system has been tested and certified by NSF. It meets the requirements of NSF Standard 41 for wastewater recycle/reuse.

COST

The installed cost of this system varies with system size and capacity as follows.

- TW-300 (100 people served) -- $70,000
- TW-3750 (1250 people served)-- $243,000
- TW-7500 (2500 people served) -- $450,000

This equipment, however, generally is leased to the building owner.

MAINTENANCE

Because the system typically is leased, operation and maintenance service is provided by Thetford Systems, Inc. Annual O&M cost range from $1000/month for the TW300 system to $5,000/month for the TW-7500 system. Cost for electricity needed for equipment operation is borne by the building owner. Annual energy consumption for the three systems is estimated to be as follows.

- TW-300 -- 15,000 kWh/year
- TW-3750 -- 70,000 kWh/year
- TW-7500 -- 115,000 kWh/year

Cromoglass Systems

Cromoglass Corporation
P.O. Box 3215
Williamsport, PA 17701
KLH Engineers, Inc.
(717) 326-3396

SYSTEM DESCRIPTION

This system operates by turbulent aeration of incoming wastes and batch treatment of biomass in separate aeration and quiescent settling chamber (Figure 4-2). A typical operating cycle is as follows:

Fill; Aeration
Flow enters the solids retention section which is separated by noncorrosive screen. Inorganic solids are retained behind the screen. Organic solids are broken by turbulence created with mixed liquor being forced through screen by submersible aeration pumps. This eliminates the need for mechanical comminution.

Aeration
Liquid and small organic solids pass through the screen into the continuing aeration section. Air and mixing are provided by submersible pumps with venturi aspirators that receive air through pipe intake from the atmosphere.

Denitrification (Optional)
Provided by an anoxic period during the regular treatment cycle. This unit creates anoxic conditions by closing the air intakes of the aeration pumps with electric valves. This stops aeration, but the system continues mixing.

Transfer/Settle
Treated mixed liquor is transferred by pumping to the clarification section. The transfer period overfills the clarifier with the excess spilling through overflow weirs back into the main aeration section. Transfer ceases and the clarifier is isolated - solids separation occurs under quiescent conditions.

Discharge
After settling, effluent is pumped out of the clarifier discharge. Sludge from the bottom of the clarifier is returned back into the main aeration section using a submersible pump or can be wasted to a sludge processing tank.

Cromoglass Systems can be installed in modules. The system can start with one independent module designed to treat the initial loading. As development grows, additional modules can be added as needed. Because a batch system requires less land area, it can be placed in multiple locations -- saving additional piping/pumping costs.

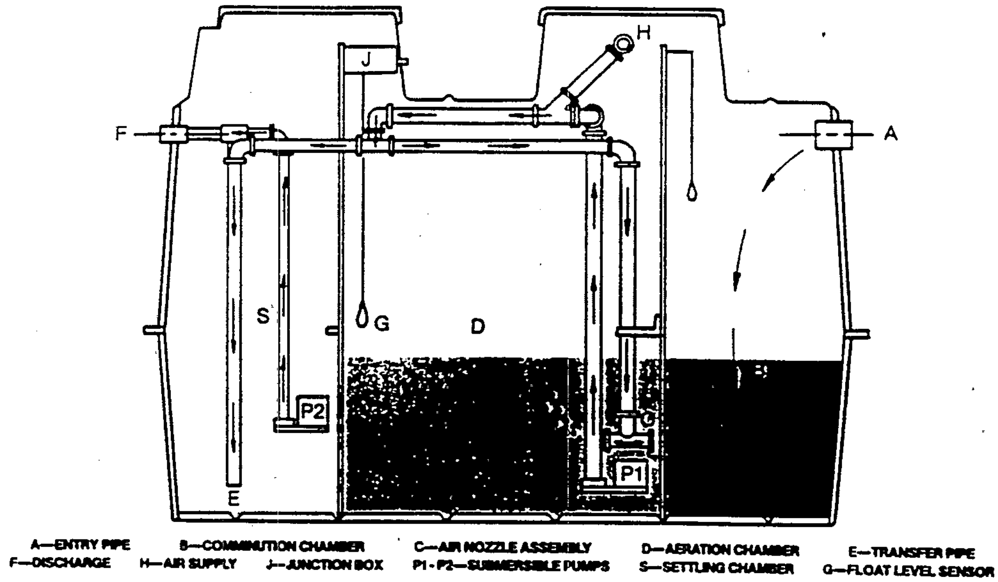


Figure 4-2: Cromoglass Wastewater Treatment and Recycling System

APPLICATIONS

Cromaglass Systems are designed for use in residential, commercial, and industrial buildings.

TESTING STATUS

Cromoglass recently has initiated a performance evaluation project in conjunction with NSF for approval using NSF Std. 41.

COST

Preliminary study indicates that this recycle capability with flows from 0 up through 12,000 GPD can be cost-effective with an individual home or similar flow system. The installed cost of this system ranges from $7,500 to $8,500.

MAINTENANCE

Periodic maintenance is required. The manufacturer/distributor recommends that this be obtained through a service agreement with a local dealer.

Orenco System
Orenco Systems, Inc.
Roseburg, Oregon
H.L. Ball
(503) 673-0165

SYSTEM DESCRIPTION

The Orenco System (Figure 4-3) collects combined wastewater in a septic tank. A pump or siphon housed in a screened vault within the septic tank doses the septic tank effluent onto the sand filter. After the effluent drains through the sand into the bottom gravel layer, it either drains out through a 4 inch PVC pipe to the drainfield or is dosed to the drainfield by a pump located in a basin in the sand filter.

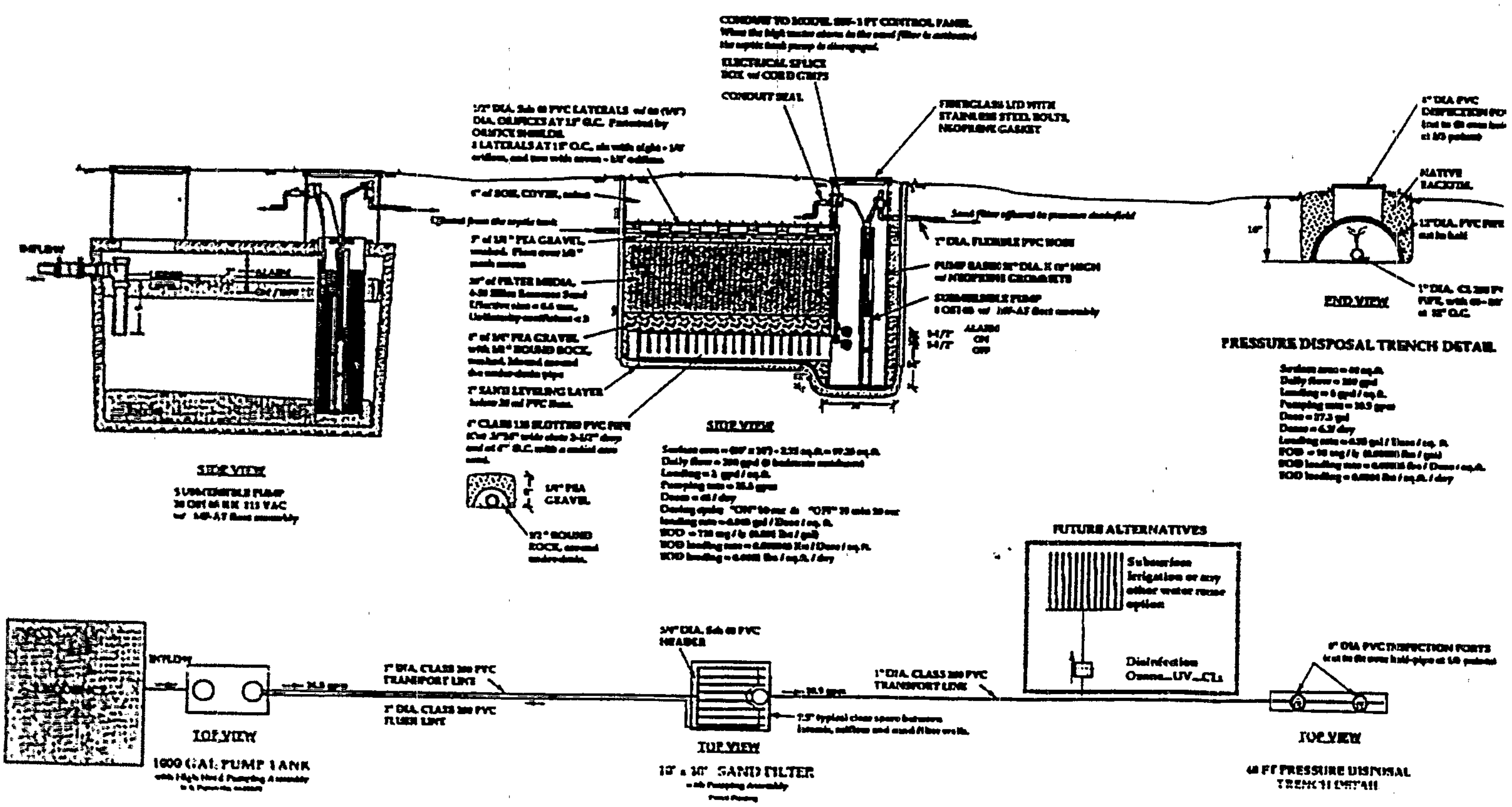


Figure 4-3: Orenco System

APPLICATIONS

The Orenco System currently is being used in residential and commercial buildings.

TESTING STATUS

This system has not been tested in accordance with NSF Std. 41.

COST

The installed cost of this system ranges from $4,500 to $7,500. Equipment and materials cost typically is 50 percent of the total initial system cost.

MAINTENANCE

Typical maintenance involves visual inspection on an annual basis, wash down of pump walls, and sludge and scum accumulation removal on a periodic basis.

Clivus Multrum, Inc.
21 Canal Street
Lawrence, Massachusetts 01840-1801
Carl Lindstrom
(508) 794-1700

SYSTEM DESCRIPTION

A typical combined wastewater treatment and recycling system (Figure 4-4) consists of solid/liquid separation over a compost reactor followed by: a septic tank, up-flow anaerobic sand filter, intermittent sand filter, drip irrigation or other reuse system.

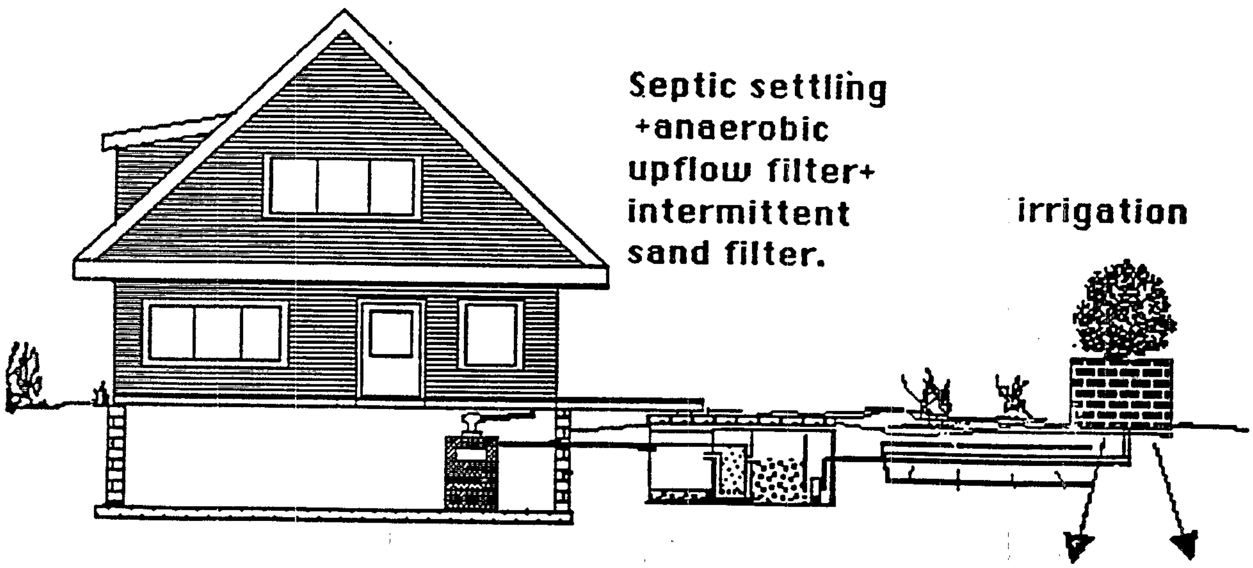


Figure 4-4: Combined Wastewater Treatment and Recycling System

APPLICATION

This system can be used in residences primarily for sub-surface irrigation purposes.

TESTING STATUS

The system currently is being tested by the University of West Virginia. However, it has not been tested by NSF.

COST

The installed cost of this system is $4,700

MAINTENANCE

The septic tank and the sand filter require maintenance on an annual basis.

V. BARRIERS AND CONSTRAINTS

On-site water treatment and recycling systems are being used both legally and illegally in the U.S. To obtain an understanding of how and where these systems are being used, and of the barriers and constraints that are restricting their widespread application, a survey of NAPHCC membership was undertaken using a standardized form (shown in Appendix C). This survey, in addition to discussions with state and local officials, revealed a variety of barriers and constraints, including: *lack of statutory authority and regulations*; *restrictive and ambiguous plumbing codes*; *lack of standards for recycled water*; *lack of confidence in standard practice for controlling cross connections*; and *preference for use of reclaimed water from a central municipal wastewater treatment plant rather than from an on-site wastewater treatment and recycling system*. Each is described briefly below.

LACK OF STATUTORY AUTHORITY AND REGULATIONS

Many states and localities do not recognize water conservation and water-reclamation activities. This is confirmed by a summary of state agencies dealing with environmental pollution control and/or wastewater discharge. As shown in Table 5-1, only 10 states have policies, recommendations, or regulations permitting the use of on-site graywater recycling systems, and only 8 states currently permit the use of on-site combined wastewater treatment and recycling systems. None of the states permit surface discharge of graywater or treated wastewater, unless discharge standards are met.

RESTRICTIVE AND AMBIGUOUS PLUMBING CODES

Each state has a unique building regulatory system. However, model codes developed by several key organizations (*e.g.*, International Conference of Building Officials, Southern Building Code Congress International, and Building Officials and Code Administrators International) are the basis for most state and local building codes. The approximate areas of influences of these codes are shown in Figure 5-1. In addition to these codes, the National Association of Plumbing-Heating-Cooling Contractors also publishes a national plumbing code, which has been adopted in New Jersey, North and South Dakota, and selected cities in Nebraska, Missouri, Pennsylvania, and New Hampshire.

Although most plumbing codes (model or state) currently do not address the use of on-site graywater recycling systems or combined wastewater treatment and recycling systems, they do not prohibit the use of these systems. Instead, the decision regarding their use is left up to the local code officials. The major concern that these officials have is the possibility of cross contamination of the potable water supply. As a result, the designer/supplier must demonstrate that the potable water supply system will not be compromised at any time. Currently, only six counties in the state of California -- Santa Barbara, San Luis Obispo, Mariposa, Los Angeles, San Bernardino, and San Diego -- have plumbing codes to permit the use of these systems. Note, however, with it is now legal to use graywater systems in California and the Department of Water

Table 5-1: States with Policies and Regulations on Graywater and Combined Wastewater Treatment and Recycling Systems

States	Graywater	Combined Wastewater Systems	Contact
Alabama			George Holcombe (205) 242-5007
Alaska			Dick Farnell (907) 465-2656
Arizona	✓		Robert Wilson (602) 257-2270
Arkansas			Patrick Harris (501) 661-2171
California	✓	✓	Dave Quinton (916)445-1248
Colorado			Phil Hegeman (303) 331-4564
Connecticut			Arthur Castellavvo (203) 566-1759
Delaware			Ron Graeber (302) 736-4762
Florida			David York (904) 488-4525
Georgia	✓		Bill McGiboney (404) 894-6644
Hawaii	✓		Felix Udasco (808) 543-8288
Idaho			Rick Mallory (208) 334-5845
Illinois			Dave Antonaccia (217) 782-4977
Indiana			Allen Dunn (317) 633-0100
Iowa			Darryl McAllister (515) 281-6682
Kansas			Steve Page (913) 296-1343
Kentucky			Dave Nichols (502) 564-4856
Louisiana			George Robichaux (504) 568-5100
Maine			Ken Meyer (207) 289-5684
Maryland	✓	✓	Jay Prager (410) 631-3652
Massachusetts			Christos Dimisioris (617) 292-5912
Michigan			Tom Hoogerhyde (517) 335-9214
Minnesota			Dave Morisette (612) 623-5517
Mississippi			Ralph Turnbow (601) 960-7696
Missouri			Nix Anderson (314) 751-6090
Montana			Rick Duncan (406) 444-2544
Nebraska			Terry Philippi (402) 471-2541
Nevada			Dale Ryan (702) 686-4750
New Hampshire			Barry Lehneman (603) 271-3505
New Jersey		✓	Bob Berg (609) 984-4429
New Mexico	✓		Bob Kirkpatrick (505) 841-9450
New York		✓	Ralph Stewart (518) 661-2171
North Carolina		✓	Tim Woody (919) 733-2895
North Dakota			Dave Bergsagel (701) 221-5210
Ohio			Tom Grigsby (614) 466-1450
Oklahoma			Dan Hodges (405) 271-7362
Oregon			Sherman Olson (503) 229-6443
Pennsylvania			Milt Lauch (717) 787-8184
Rhode Island			Mark Boucher (401) 227-2306
South Carolina			Leonard Gordon (803) 734-5096
South Dakota	✓		Bill Baer (605) 773-3296
Tennessee	✓		Steve Morse (615) 741-0690
Texas	✓	✓	Sherman Hart (512) 458-7375
Utah			Don Hanson (801) 538-6159
Vermont			Ernie Christianson (802) 879-6563
Virginia	✓	✓	Alan Knapp (804) 786-1750
Washington			Don Alexander (804) 786-1750
West Virginia			Ron Forren (304) 348-2971
Wisconsin			Dave Russell (608) 266-0056
Wyoming			John Harrison (307) 777-7431

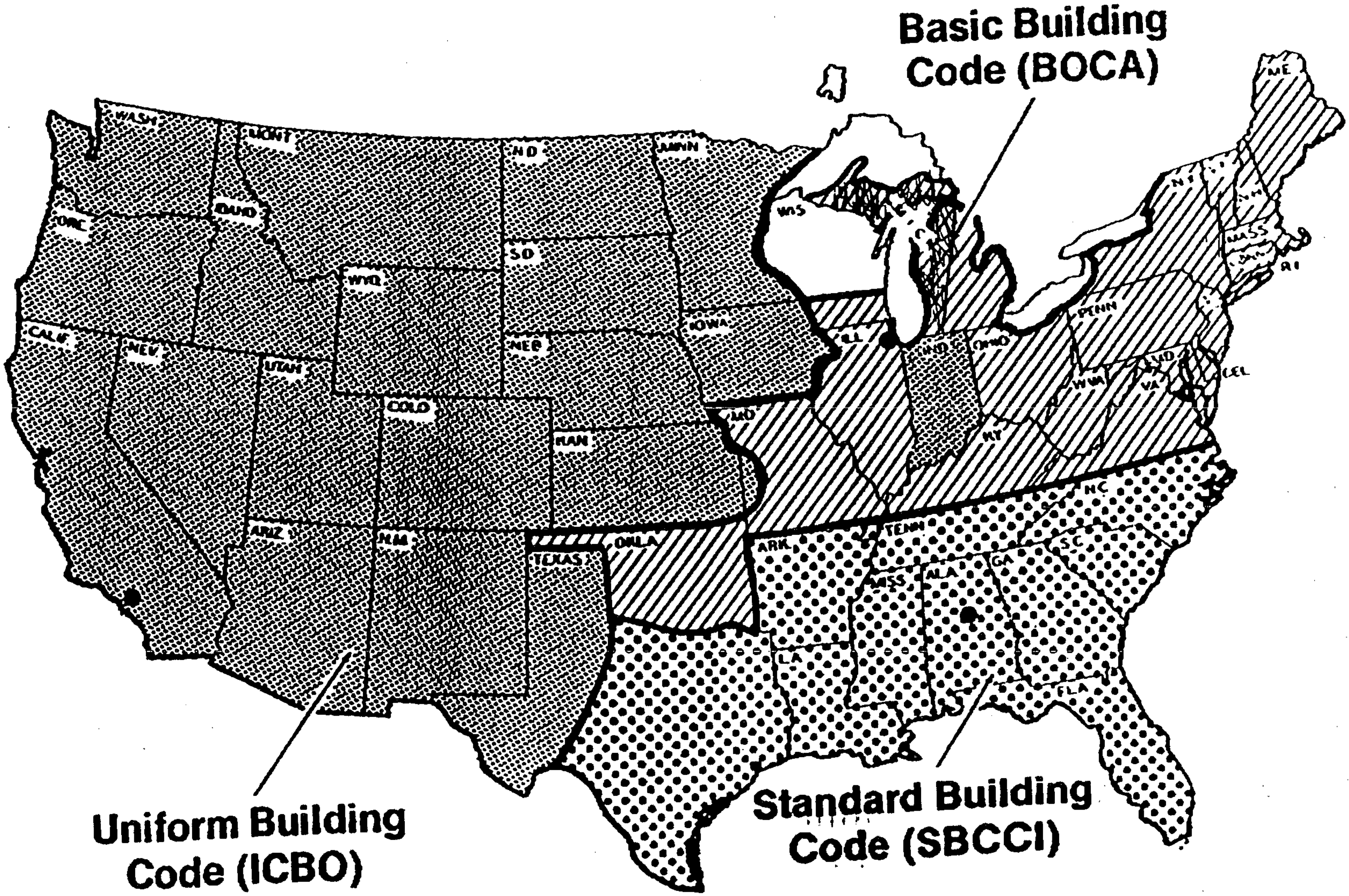


Figure 5-1: Approximate Areas of Building Code Influences

Resources has till July 1, 1993 to develop and adopt installation standards for on-site graywater systems. Further, the Chief Plumbing Inspector of Los Angeles County in California recently has presented the Ad-hoc Graywater Committee's proposed code changes relative to on-site graywater recycling systems to the International Association of Plumbing & Mechanical Officials for consideration. A copy of the proposed modifications is included in Appendix B.

Most states and localities make technical amendments when they adopt a model code and many have provisions which allow the use of special design plumbing systems which vary in detail from the requirements of the specific code. These provisions typically require:

- Submission of plans, specifications and computations and other related data for the special design.
- Installation and testing in accordance with approved criteria.
- Certification of compliance by an approved independent agency.

Although such provisions permit the use of on-site graywater recycling systems and combined wastewater treatment and recycling systems on an experimental basis, other governing state and local regulations must also be adhered to. The process of obtaining approvals is time-consuming and can be expensive, thus deterring the use of such special systems.

LACK OF A NATIONAL STANDARD FOR ON-SITE RECYCLED WATER QUALITY

The National Sanitation Foundation has established a minimum quality standard for recycled wastewater with its certification Standard No. 41. However, it is not a nationally accepted standard. As a result, each state and each county must establish its own standard and develop its own regulations with regards to the use of on-site graywater recycling and combined wastewater treatment and recycling systems. The regulatory process is generally slow to respond; therefore, the market for on-site wastewater treatment and recycling systems currently is small and fragmented. If a uniform national standard was developed, however, there would be more acceptance of these systems and the cost of the equipment would decline significantly. Estimates from manufacturers indicate that cost could decline by as much as 50 percent of current prices.

LACK OF CONFIDENCE IN STANDARD PRACTICE FOR CONTROLLING CROSS CONNECTIONS

Although all the experience with using reclaimed water for toilet flushing has been successful, many building and safety departments are reluctant to consider using non-potable water in a building because of the lack of experience with procedures used to control dual water systems.

PREFERENCE FOR RECLAIMING WATER FROM MUNICIPAL WASTEWATER TREATMENT PLANT RATHER THAN ON-SITE WASTEWATER TREATMENT AND RECYCLING

The number, size, and capacity of projects involving reclaimed water from central municipal wastewater treatment plants is growing. Today, there are 18 states (Table 5-2) that currently have regulations for reuse of reclaimed water; another 18 states have published guidelines for reuse of reclaimed water; and 14 states do not currently have regulations or guidelines for reuse of reclaimed water. (35)

There is a growing awareness that recycling of wastewater is an important strategy for water conservation and peak reduction. However, public health and building officials in many states prefer the use of reclaimed water from central municipal plants rather than the use of recycled water from on-site wastewater treatment and recycling systems. These individuals emphasize that reclaimed water has superior quality and offers lower health risks. In addition, centralized operation permits better control over the operation and maintenance of the system. Furthermore, reclaimed water from central municipal plants is a major revenue source for the localities that employ it. This mind set of public health and building officials continues to limit the widespread use of on-site wastewater treatment and recycling systems.

Table 5-2: Summary of State Reuse Regulations and Guidelines

STATE	Regulations	Guidelines	No Regulations	Unrestricted Urban Reuse	Restricted Urban Re-use	Agricultural Reuse Food Crops	Agricultural Reuse Non-Food Crops	Unrestricted Recreational Reuse	Restricted Recreational Reuse	Environmental Reuse	Industrial Reuse
Alabama		✓					✓				
Alaska			✓								
Arizona	✓			✓	✓	✓	✓	✓	✓	✓	
Arkansas		✓		✓	✓	✓	✓				
California	✓			✓	✓	✓	✓	✓	✓		
Colorado		✓		✓	✓	✓	✓	✓	✓		
Connecticut			✓								
Delaware		✓		✓	✓		✓				
Florida	✓			✓	✓	✓	✓			✓	
Georgia		✓		✓	✓		✓				
Hawaii		✓[1]		✓	✓	✓	✓		✓		✓
Idaho	✓			✓	✓	✓	✓				
Illinois	✓[1]			✓	✓		✓				
Indiana	✓					✓	✓				
Iowa			✓								
Kansas		✓		✓	✓	✓	✓				
Kentucky			✓								
Louisiana			✓								
Maine			✓								
Maryland		✓			✓		✓				
Massachusetts			✓								
Michigan	✓					✓	✓				
Minnesota			✓								
Mississippi			✓								
Missouri	✓										

[1]Draft or proposed

Source: Reference #35

Table 5-2: Summary of State Reuse Regulations and Guidelines

STATE	Regulations	Guidelines	No Regulations	Unrestricted Urban Reuse	Restricted Urban Re-use	Agricultural Reuse Food Crops	Agricultural Reuse Non-Food Crops	Unrestricted Recreational Reuse	Restricted Recreational Reuse	Environmental Reuse	Industrial Reuse
Montana		✓		✓	✓	✓	✓				
Nebraska		✓			✓		✓				
Nevada		✓[1]		✓	✓	✓	✓	✓	✓		✓
N. Hampshire			✓								
New Jersey	✓						✓				
New Mexico		✓		✓	✓	✓	✓				
New York		✓					✓				
North Carolina	✓				✓						
North Dakota		✓					✓				
Ohio			✓								
Oklahoma		✓			✓		✓				
Oregon	✓			✓	✓	✓	✓	✓	✓		✓
Pennsylvania			✓								
Rhode Island											
S. Carolina		✓		✓	✓		✓				
South Dakota		✓		✓	✓		✓			✓	
Tennessee	✓			✓	✓		✓				
Texas	✓			✓	✓	✓	✓		✓		✓
Utah	✓			✓	✓	✓	✓				✓
Vermont	✓						✓				
Virginia			✓								
Washington		✓		✓	✓	✓	✓				
West Virginia	✓					✓	✓				
Wisconsin	✓						✓				
Wyoming	✓			✓	✓	✓	✓				

[1]Draft or proposed

Source: Reference #35

VI. ECONOMICS OF ON-SITE WASTEWATER TREATMENT AND RECYCLING SYSTEMS

Cost is most often the determining factor in making decisions with regards to which recycling system is best for the application. It also is the criteria used when deciding between installing an on-site treatment and recycling system and purchasing reclaimed water from a central, municipal water treatment plant.

Major cost criteria used by most homeowners and commercial/institutional building developers and owners is initial system cost. However, many commercial and industrial building owners that occupy their own buildings base their decisions on life cycle cost analysis which also considers the dollar value of the benefits. Other factors that owners consider in decision-making include wastewater reuse potential in the building, system reliability and flexibility, ease with which plumbing modifications can be made, and space requirements for installation of storage tanks and other equipment.

Numerous factors should be specifically addressed when evaluating the economics of on-site wastewater treatment and recycling system options. These include the design, components, and the method of payment that contribute to the initial system cost; alternative methods of acquiring the system hardware; operating and maintenance costs, including energy, parts, and labor; interest rates; the economic life of the system; the discount rate; and the value of tangible and intangible benefits from the system.

ECONOMIC FACTORS

Economic evaluations should consider a variety of factors. The following discussion identifies some of the major factors which should be considered in any life cycle cost analysis.

Initial Cost

Initial cost includes the cost of design, system components, the cost of shipping these components, the taxes involved, and the cost of installation. In existing situations, the cost of on-site wastewater treatment and recycling system must also include any associated modifications of the plumbing system components or layout.

The initial cost of a graywater system installed in a single-family residential or small commercial application typically ranges from $500, for a basic "no-frills" system, to $5,000, for a fully automated system; the cost of a on-site combined wastewater treatment and recycling system for the same application ranges from $4,500 to $8,500. Initial costs for on-site combined wastewater treatment and recycling systems in larger commercial and industrial facilities typically are approximately $1.00 per gross square foot. This includes the cost of the equipment, cost of building space, and the cost of return on potable water supply. It also includes the cost of standby sanitary sewer connection required by some systems to provide emergency service and periodic residual solids disposal.

Estimates of initial costs should be reduced by any water conservation credits that may be offered by water utilities. Such credits currently are not available. In the future, however, water utilities may offer such credits to encourage water conservation and peak reduction through use of on-site wastewater treatment and recycling systems.

Currently, there are only two options available for the acquiring graywater and combined wastewater treatment and recycling systems. These are: *direct purchase* and *leasing*. Although direct purchase currently is the most commonly used method, a few manufacturers offer lease agreements. Under a lease agreement, a lessor usually completely finances the purchase and installation of the on-site wastewater treatment and recycling system in a building. The lessee (building owner) makes monthly payments to the lessor (owner of equipment) for the use of the equipment. In some lease agreements, the owner pays for the on-site plumbing modifications, whereas the lessor finances the initial purchase of the equipment.

As on-site wastewater treatment and recycling systems become more accepted and their use becomes more widespread, shared water savings (SWS) contracts (similar to shared energy contracts) may become a viable option in large commercial and industrial applications. Under a SWS arrangement, a third party designs, installs, and owns the wastewater treatment and recycling system at the owner's facility, then the owner and third party split the cost savings that result due to water conservation.

Operating Costs

Operating costs are related principally to energy and demand. Energy is consumed in on-site graywater and combined wastewater treatment and recycling systems by electric motors that operate pumps and aeration equipment and by disinfection equipment (*e.g.*, ultraviolet lamps). These costs vary widely depending upon the system being considered and, thus, should be obtained from the manufacturers. One manufacturer (Thetford Systems, Inc.) did provide estimates of annual energy consumption for its graywater systems for applications in hotels, motels, and recreational facilities. These range from 13,000 kWh (for 350 gpd system) to 95,000 kWh (for a 8,500 gpd system).

In making long-term calculations, it is important to consider the energy rates likely to be in effect over the life of the system. Projected energy rates should be obtained from the local electric utility.

Economic Life

The economic life of a on-site wastewater treatment and recycling system can be determined in a variety of ways. One is to base it on the anticipated design life of the system itself. Another is to base it on the anticipated life or remaining life of the building involved. The economic life of on-site wastewater treatment and recycling systems considered for life cycle costs analysis typically is 20 years.

Maintenance Costs

Maintenance costs also can be projected on an annualized basis. They include the cost of replacement parts, replacement labor, filter cleaning labor, equipment repair, and cost of maintaining control systems.

For residential and small commercial applications, the annual maintenance cost associated with graywater systems is about $50 to $100, including the cost of filter replacement and labor for periodic maintenance and flushing of the system. For on-site combined wastewater treatment and recycling systems in large commercial and industrial applications, the annual maintenance costs typically are about 2 percent of initial equipment cost or approximately $0.15 per gross square foot.

Interest Rate

Because almost all commercial and industrial construction and modifications are financed, the interest rate paid for borrowed funds determines the real cost of a system and its components.

Discount Rate

The discount rate is an interest rate applied in reverse to determine the present value of future money. One dollar received today is more valuable than one dollar received a year from today because today's dollar can be invested in a secure, insured account. It will have grown to more than a dollar by the end of a year. For example, if one assumes a 6 percent interest rate can be earned with ease, then one dollar received today will be worth $1.06 in one year.

The discount rate is applied to determine how much future money (income or expense) is worth today. Once again, the rate applied is that rate which can be earned easily and safely. Thus, assuming the rate is 6 percent, $1.06 received one year from today would be worth $1.00 today:

$1.06 - ($1.00 x 0.06) = $1.00

Likewise, $1.00 received one year from today would be worth only $0.94 now.

Using this approach, one can take future expenses associated with a system, adjust for inflation, and apply a discount rate to determine the present value of these expenses. The present worth or present value can then be divided by the economic life of the proposed system to develop annualized cost data in present-worth dollars.

Most texts on engineering economics provide comprehensive charts of factors that can be used to determine the present value of future money quickly and easily using a number of different discount rates.

In retrofit applications, this approach is frequently applied to determine whether it is worthwhile to make an investment in water conservation. Using this approach, one computes the future value of savings in terms of present-value dollars.

Value of Benefits

It is difficult to assign value to the benefits provided by on-site graywater and combined wastewater treatment and recycling systems. Nonetheless, it is appropriate to apply at least conservative approximations when they are warranted. As example, graywater recycling in a commercial laundry facility provides an added value of reduced energy costs. Recovered graywater is warm and heat can be recovered from this wastewater through use of a heat exchanger to preheat domestic hot water. Although there are initial costs associated with heat recovery, the energy cost savings due to heat recovery can more than offset the initial cost of the equipment, resulting in a quick payback. In addition, because recycled graywater contains nutrients -- nitrogen, phosphorus, and potassium -- less fertilizer may be required in many applications involving landscape irrigation. As such, the fertilizer value of graywater should be accounted for.

Furthermore, many commercial buildings that are likely candidates for combined wastewater treatment and recycling systems cannot be developed without it. Many buildings are located in areas which are not served by public sewer and on-site problems prohibit a large sanitary leachfield. In this situation, the value of the property becomes dependent, not on its favorable location, but on its ability to provide sanitary facilities to employees and customers. Here, wastewater recycling adds value to the property. It makes the difference as to whether the site can be developed at all and, if so, what types of uses can be incorporated. In such instances, the ability to develop the site or to simply increase the density of the development will add value far in excess of the cost of the wastewater treatment and recycling system.

ECONOMICS OF ON-SITE WASTEWATER TREATMENT AND RECYCLING VERSUS RECLAIMED WATER FROM A CENTRAL PLANT

The trend in water reuse is one of growth. Many cities and counties in semi-arid and arid areas are modifying their wastewater treatment plants and distribution systems to reclaim wastewater for landscape irrigation in public facilities like golf courses, schools, and parks. Although little competition exists between reclaimed water from central municipal facilities and on-site wastewater treatment and recycling systems, this may change in the future as reclaimed water is sold by municipalities to building owners for reuse in toilets, cooling towers, and for other purposes.

Decisions on whether reclaimed water or on-site recycling is the most cost-effective water reuse method should be based on life cycle cost analysis. The initial operation and maintenance costs associated with on-site wastewater treatment and recycling systems have already been discussed above. The initial costs associated with delivered reclaimed water from a large scale central municipal reclamation plant include the following costs:

- Biological and physical/chemical treatment
- Water storage
- Water pumping stations
- Distribution piping
- Operational controls

The components of the operation and maintenance costs are as follows.

- Monthly fee for reclaimed water
- Labor to operate and maintain the system
- Electricity to operate pumps and controls
- Chemicals for disinfection and coagulation
- Replacement parts for pumps, motors, *etc.*

In addition to the above, the cost of disruption to existing infrastructure and community should be considered, as well as the cost to the end-user. These costs are as follows.

- Initial connection fees
- Modifications of building plumbing system
- Cross connection protection
- Modifications to irrigation systems (if these are contemplated)

VII. GLOSSARY

Alarm	An instrument or device which continuously monitors a specific function of a treatment process and automatically gives warning of an unsafe or undesirable condition by means of visual and/or audible signals.
Biochemical oxygen demand (BOD)	The quantity of oxygen utilized in the biochemical oxidation of organic matter present in water or wastewater, reported as a five-day value established as determined using approved methods.
Biological Treatment	Methods of wastewater treatment in which bacteria or other living organisms treat the wastewater.
Blackwater	Water that is flushed from toilets and urinals that contains human waste.
BOD_5	Five day biochemical oxygen demand -- a standard test indicating the quantity of oxygen utilized in five days by wastewater under controlled temperature conditions.
Disinfection	The destruction of pathogens in wastewater effluents.
Dosing chamber	Tank in which premeasured chemicals are mixed with wastewater <u>or</u> that stores pretreated wastewater for periodic pressurized discharges.
Edible crops	Crops intended for human consumption.
Effluent limitation	Restriction on quantities, rates, or concentrations of chemical, physical, biological, or other constituents which are discharged to receiving waters.
Effluent	Partially or completely treated wastewater discharged from a wastewater treatment system.
Fecal coliforms	Members of the coliform bacteria group capable of producing gas from lactose at 44.5 degree C, as determined using approved methods.
Graywater	Water from washing machines, bathtubs, showers, and bathrooms sinks.
Landscape irrigation	Irrigation of lawns, trees, and shrubs on residential, commercial and institutional properties.

Milligrams per liter (mg/l)	The quantity of material present in water or wastewater expressed on the basis of the weight (milligrams) per unit volume of solution (liter).
On-site wastewater system	System designed to contain, distribute, or treat wastewater on or near the location where the wastewater is generated.
Potable water	Water that meets drinking water standards.
Reclaimed water	Effluent from a wastewater treatment facility that has been subjected to extensive treatment in order to remove organic material, heavy metals, and harmful pathogens (such as bacteria, viruses, and protozoa) to a level acceptable for specific uses.
Reuse	The deliberate application of recovered wastewater for a beneficial purpose.
Sedimentation tank	A watertight basin or tank in which liquid wastewater containing settleable solids and suspended matter settle out by gravity.
Septic Tank	A watertight receptacle which receives the raw wastewater and discharges a settled, partially treated effluent, usually to a leach field.
SS	Suspended solids present in wastewater.
Subsurface irrigation system	A network of small diameter, porous or perforated pipes installed horizontally at depth generally less than 12 inches for the purpose of releasing water at or near the root zone of vegetation.
Total Kjeldahl Nitrogen (TKN)	The sum of free ammonia and organic nitrogen compounds in water or wastewater and expressed as elemental nitrogen, N, as determined using approved methods.
Total suspended solids (TSS)	Solids that either float on the surface or are suspended in, water or wastewater; the quantity of material removed from a simple in a laboratory test referred to as nonfilterable residue, as determined using approved methods.
Treatment	Any method, technique, or process which changes the physical, chemical, or biological character or composition of wastewater.

Turbidity A condition in water or wastewater caused by the presence of suspended matter, resulting in the scattering and absorption of light rays, as determined using approved methods.

Wastewater The combination of liquid and water-carried pollutants from residences, commercial buildings, industrial plants, and institutions.

VIII. REFERENCES

1. Olsson, Eskill, Karlgren, L., and Tullander, V., Household Wastewater, The National Swedish Institute for Building Research, Box 26 163 - 102 52 Stockholm 27, Sweden, 1968

2. Wallman, H. and S. Cohen, Demonstration of Waste Flow Reduction from Households, U.S. Environmental Protection Agency Report EPA 670/2-74-071, September, 1974.

3. Ligman, K., N. Hutzler, and W.C. Boyle, "Household Wastewater Characterization," Journal of the Environmental Engineering Division, ASCE, Vol. 150, No. EEI, Proc. Paper 10372, February, 1974.

4. Laak, R., Relative Pollution Strengths of Undiluted Waste materials Discharged in Households and the Dilution Waters Used for Each, Manual of Grey Water Treatment Practice - Part II, Monogram Industries, Inc., Santa Monica, California, 1975.

5. Bennett, E.R. and E.K. Linstedt, Individual Home Wastewater Characterization and Treatment, Completion Report Series No. 66, Environmental Resources Center, Colorado State University, Fort Collins, Colorado, July, 1975.

6. Siegrist, R., M. Witt and W.C. Boyle, "Characteristics of Rural Household Wastewater," Journal of the Environmental Engineering Division, ASCE, Vol. 102, No. EE3, Proc. Paper 12200, June, 1976.

7. Siegrist, R., Segregation and Separate Treatment of Black and Grey Household Wastewaters to Facilitate On-Site Surface Disposal, Small Scale Management Project, University of Wisconsin, Madison Wisconsin, 1977.

8. Karpiscak, M.M., K.E. Foster, K.J. DeCook, C.P. Gerba and R. Brittain, Summary Report on Phase II Casa del Agua: A Community Water Conservation Demonstration and Evaluation Project, University of Arizona, Tuscon, Arizona, 1987.

9. State-of-the-Art Assessment of Compost Toilets and Greywater Treatment Systems, The Wintrop Rockefeller Foundation, Little Rock, Arkansas, Feb. 1980.

10. Siegrist, R., An Evaluation of the Potential for Pathogenic Contamination of Household Grey Water, Small Scale Waste Management Project, University of Wisconsin, Madison, Wisconsin, February 1977.

11. Brandes, M., Characteristics of Effluents from Gray and Black Water Septic Tanks, JWPCF, Vol. 50, No. 11, November, 1978.

12. Boyle, W.C., R.R. Siegrist, Chin C. Saw, Treatment of Residential Graywater With Intermittent Sand Filtration, Alternative Wastewater Treatment, 1982.

13. State of California, Department of Health Services, Environmental Management Branch, Hazards Related to Graywater, Unpublished Technical Report, 1990.

14. CCDEH Issue Paper: Graywater Use in California, California Conference of Directors of Environmental Health, Ventura County, CA. 1992.

15. Rose, J.B., M.M. Karpiscak, K.E. Foster, K.J. DeCook, C.P. Gerba and R. Brittain, An Experiment in Residential Water Reuse and Conservation, Water Resuse Symposium IV, American Water Works Association, August 2-7, Denver.

16. McCoy, E. and W.A. Ziebell, Effects of Effluents on Groundwater: Bacteriological Aspects, Proceedings of the National Sanitation Foundation Conference on Individual On-Site Wastewater Systems, Ann Arbor, Michigan, November, 1975.

17. Graywater Pilot Project (Mid-Course Report), Office of Water Reclamation, City of Los Angeles, Califronia, June 1992.

18. Proposed Code Change to a Section and/or Sections of the UPC-USPC-USEC, Submitted to the National Association of Plumbing and Mechanical Officials, Los Angeles, California, February 1992.

19. Cohen, S., and Wallman, H., Demonstration of Waste Flow Reduction from Households, U.S. EPA 670/2-74-071, (September, 1974).

20. Hypes, W.E., Batten, C.E., and Wilkins, J.R., Processing of Combined Domestic Bath and Laundry Wastewater for Reuse as Commode Flushing Water, NASA Technical Note, NASA TN D-7937, (October, 1975).

21. University of Wisconsin, Small Scale Waste Management Project, 1977. Final report submitted U.S.E.P.A. in fulfillment of Grant No. R802874-01.

22. Siegrist, R.L., Management of Residential Greywater, Department of Civil and Environmental Engineering, Small Scale Waste Management Project, University of Wisconsin, Madison, 1978.

23. Hypes, W.D., Batten, C.E., and Wilkins, J.R., The Chemical/Physical and Microbiological Characteristics of Typical Bath and Laundry Washwaters, NASA Technical Note, NASA TN D-7566 (March, 1974)

24. Lent, D.S., "Treatment of Power Laundry Wastewater Utilizing Powered Activated Carbon and Cationic Polyelectrolyte," Proceedings Purdue University Industrial Wastewater Conference XXX, 751, (1975).

25. Small Scale Wastewater Management Project-Draft Report, Appendix A, University of Wisconsin, Madison, Wisconsin, (1977).

26. Hoover, P.R., McNalty, K.J., and Goldsmith, R.L., Evaluation of Ultrafiltration and Disinfection for Treatment of Blackwater, U.S. Army Mobility Equipment Research and Development Command, Fort Belvoir, Virginia, (1977).

27. Barrows, John. "Understanding Ozone: The Most Effective Sanitizer," Manufacturing Engineer, Del Industries, Inc., 1992.

28. Saver, D.K., Dry Feed Chlorination of Wastewater On-Site' Small-Scale Waste Management Project, University of Wisconsin, Madison, Wisconsin (1976).

29. Budde, P.E., Nehm, P., and Boyle, W.C., "Alternatives to Wastewater Disinfection," JWPCF 49(10): 2144-2156, (1977).

30. "Graywater," City Department of Public Works and Building and Zoning Division, City of Santa Barbara, California, April 1990

31. ""Guidelines for Approved Use in Residential Landscapes in the City and County of San Luis Obispo," City and County of San Obispo, California, 1991.

32. "Residential Greywater Treatment and Use By Subsurface Irrigation Systems," Carlile & Associates, Inc., San Francisco, California, 1991.

33. Whitworth, Patrick L. "Designing Grey Water Recovery Systems," Plumbing Engineer, March 1991, pp. 18-23.

34. Karpiscak, Martin K. et al. Domestic Greywater: A Review of Alternatives for Its Treatment and Uses (Draft), University of Arizona, February 1992.

35. Camp, Dresser and McKee, Water Reuse Regulations and Guidelines (Draft), Environmental Protection Agency and Agency for International Development, Washington, District of Columbia, March 1992.

36. How to Use Graywater: Guidelines to the Approved Use of Graywater in Santa Barbara County, Gray Water Technical Advisory Committee, County of Santa Barbara, California, May 1991.

APPENDIX A:
WORKPLAN FOR THE EVALUATION OF THE DISTRIBUTION OF GRAYWATER THROUGH SUBSURFACE DRIP IRRIGATION

INTERNATIONAL ASSOCIATION OF PLUMBING AND MECHANICAL OFFICIALS

PROPOSED CODE CHANGE TO A SECTION AND/OR SECTIONS OF THE UPC–USPC–USEC

Note: All Code Sections that may be affected by this change must be listed;

Name Fady Mattar, Chief Plumbing Inspector Class of Membership A

Jurisdiction/Company You Represent Los Angeles County, California Date Feb 20,1992

Mailing Address 900 S. Fremont Avenue, Third Floor

City Alhambra State CA Zip 91803

THE FOLLOWING AMENDMENT IS SUBMITTED:

Add APPENDIX W Entitled GRAYWATER SYSTEMS FOR SINGLE FAMILY DWELLINGS

See Attached

REASON FOR CODE REVISION:

The code does not currently define graywater or set standards for the design and construction of graywater collection and distribution systems. Since 1989, six California counties, with more than ten million residents, have approved the use of graywater.

The California Ad-Hoc Graywater Committee was formed in May 1991 to investigate whether graywater could be safely used. The formation of the Committee was prompted b public interest in the use of graywater as a water conservation measure, especially durin the continuing drought.

The Ad-Hoc Committee is composed of representatives of the California Conference of Directors of Environmental Health, the California Mosquito & Vector Control Association the California Association of Building Officials, the Building Standards Commission, the International Association of Plumbing and Mechanical Officials, the Los Angeles Count Building & Safety Department, the Association of California Water Agencies, the City of L Angeles Office of Water Reclamation, the WateReuse Association of California, the Sierra Club, the Department of Health Services, the State Water Resources Control Board, and th Department of Water Resources.

The Committee developed this draft UPC Graywater Appendix to provide guidance (an maximum safety) to any jurisdiction considering the legalization of graywater installations.

Use additional sheets if necessary Do not write below this li

CODE CHANGE	COMMITTEE'S RECOMMENDATION	No.

AIPMO-PCC-2-89 5M

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APPENDIX W GRAYWATER SYSTEMS FOR SINGLE FAMILY DWELLINGS

Section W-1 Graywater Systems. (General)

(a) The provisions of this Appendix shall apply to the construction, alteration and repair of graywater systems for underground landscape irrigation. Installations shall be allowed only in single family dwellings. The system shall have no connection to any potable water system and shall not result in any surfacing of the graywater. Except as otherwise provided for in this Appendix, the provisions of this Code shall be applicable to graywater installations.

(b) The type of system shall be determined on the basis of location, soil type, and groundwater level and shall be designed to accept all graywater connected to the system from the residential building. The system, except as otherwise approved, shall consist of holding tank(s) which discharge into subsurface irrigation/disposal fields.

(c) No graywater system, or part thereof, shall be located on any lot other than the lot which is the site of the building or structure which discharges the graywater; nor shall any graywater system or part thereof be located at any point having less than the minimum distances indicated in Table W-1.

(d) No permit for any graywater system shall be issued until a plot plan with appropriate data satisfactory to the Administrative Authority has been submitted and approved. When there is insufficient lot area or inappropriate soil conditions for adequate absorption of the graywater, as determined by the Administrative Authority, no graywater system shall be permitted.

(e) No permit shall be issued for a graywater system on any property in a geologically sensitive area as determined by the Administrative Authority.

(f) Private sewage disposal systems existing or to be constructed on the premises shall comply with Appendix I of this Code. In addition, appropriate clearances from the graywater systems shall be maintained as provided in Table W-1. The capacity of the private sewage disposal system, including required future areas, shall not be decreased or otherwise affected by the existence or proposed installation of a graywater system servicing the premises.

Section W-2 Definition.

Graywater is untreated household waste water which has not come into contact with toilet waste. Graywater includes used water from bathtubs, showers, bathroom wash basins, and water from clothes washing machines and laundry tubs. It shall not include waste water from kitchen sinks or dishwashers.

Section W-3 Permit.

It shall be unlawful for any person to construct, install or alter, or cause to be constructed, installed or altered any graywater system in a building or on a premises without first obtaining a permit to do such work from the Administrative Authority.

Section W-4 Drawings and Specifications.

The Administrative Authority may require any or all of the following information to be included with or in the plot plan before a permit is issued for a graywater system or at any time during the construction thereof:

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(a) Plot plan drawn to scale completely dimensioned, showing lot lines and structures, direction and approximate slope of surface, location of all present or proposed retaining walls, drainage channels, water supply lines, wells, paved areas and structures on the plot, number of bedrooms and plumbing fixtures in each structure, location of private sewage disposal system and 100% expansion area or building sewer connecting to public sewer, and location of the proposed graywater system.

(b) Details of construction necessary to assure compliance with the requirements of this Appendix together with a full description of the complete installation including installation methods, construction and materials as required by the Administrative Authority.

(c) A log of soil formations and groundwater level as determined by test holes dug in close proximity to any proposed irrigation area, together with a statement of water absorption characteristics of the soil at the proposed site as determined by approved percolation tests. Exception: the Administrative Authority may allow the use of Table W-2 in lieu of percolation tests.

Section W-5 Inspection and Testing.

(a) Inspection

1. All applicable provisions of this Appendix and of Section 318 of this Code shall be complied with.
2. System components shall be properly identified as to manufacturer.
3. Holding tanks shall be installed on dry, level, well-compacted soil, if underground, or on a level, 3" concrete slab if above ground.
4. Holding tanks shall be anchored against overturning.
5. If design is predicated on soil tests, the irrigation/disposal field shall be installed at the same location and depth as the tested area.
6. Installation shall conform with the equipment and installation methods identified in the approved plans.

(b) Testing

1. Holding tanks shall be filled with water to the overflow line prior to and during inspection. All seams and joints shall be left exposed and the tank shall remain watertight.
2. A flow test shall be performed through the system to the point of graywater irrigation/disposal. All lines and components shall be watertight.

Section W-6 Procedure for Estimating graywater Discharge.

(a) The number of occupants of each dwelling unit shall be calculated as follows:

First Bedroom	2 occupants
Each additional bedroom	1 occupant

(b) The estimated graywater flows for each occupant shall be calculated as follows:

Showers, bathtubs and wash basins	25 GPD/occupant.
Laundry	15 GPD/occupant.

(c) The total number of occupants shall be multiplied by the applicable estimated graywater discharge as provided above and the type of fixtures connected to the graywater system.

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EXAMPLE 1.

Single Family Dwelling, 3 bedrooms with showers, bathtubs, wash basins and laundry facilities all connected to the graywater system:

Total number of occupants = 2 +1+1 = 4

Estimated graywater flow = 4 x (25 +15) = 160 GPD

EXAMPLE 2.

Singly Family Dwelling, 4 bedrooms with only the clothes washers connected to the graywater system:

Total number of occupants = 2+1+1+1 = 5

Estimated graywater flow = 5 x 15 = 75 GPD

Section W-7 Required Area of Subsurface Irrigation/Disposal Fields. (Fig. 5)

Each valved zone shall have a minimum effective irrigation area in square feet as determined by Table W-2 for the type of soil found in the excavation, based upon a calculation of estimated graywater discharge pursuant to Section W-6 of this Appendix, or the size of the holding tank, whichever is larger. The area of the irrigation/disposal field shall be equal to the aggregate length of the perforated pipe sections within the valved zone times the width of the proposed irrigation/disposal field. Each proposed graywater system shall include at least three valved zones and each zone must be in compliance with the provisions of this Section. No excavation for an irrigation/disposal field shall extend within five (5) vertical feet of highest known seasonal groundwater nor to a depth where graywater may contaminate the groundwater or ocean water. The applicant shall supply evidence of groundwater depth to the satisfaction of the Administrative Authority.

Section W-8 Determination of Maximum Absorption Capacity.

(a) Wherever practicable, irrigation/disposal field size shall be computed from Table W-2.

(b) In order to determine the absorption quantities of questionable soils other than those listed in Table W-2, the proposed site may be subjected to percolation tests acceptable to the Administrative Authority .

(c) When a percolation test is required, no graywater system shall be permitted if the test shows the absorption capacity of the soil is less than 0.83 gallons per sq. ft. or more than 5.12 gallons per sq. ft. of leaching area per 24 hours.

Section W-9 Holding Tank Construction. (FIG. 1, 2, 3 & 4)

(a) Plans for all holding tanks shall be submitted to the Administrative Authority for approval. Such plans shall show all dimensions, structural calculations, bracings and such other pertinent data as may be required. A minimum capacity of fifty gallons is required.

(b) Holding tanks shall be constructed of solid durable materials, not subject to excessive corrosion or decay and shall be watertight.

(c) Each holding tank shall be vented as required by Chapter 5 of this Code and shall have a locking, gasketed access opening, or approved equivalent, to allow for inspection and cleaning.

(d) Each holding tank shall have its rated capacity permanently marked on the unit. In addition, a sign "GRAYWATER IRRIGATION SYSTEM, DANGER - UNSAFE WATER" shall be permanently marked on the holding tank.

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(e) Each holding tank installed above ground shall have an emergency drain, separate from that connecting the tank with the irrigation/disposal fields, and an overflow drain. The emergency and overflow drains shall have permanent connections to the building drain or building sewer, upstream of septic tanks, if any. The overflow drain shall not be equipped with a shut-off valve.

(f) The overflow and emergency drain pipes shall not be less in size than the inlet pipe. Th vent size shall be determined based on the total graywater fixture units, as outlined in UPC Table 4-3 of this Code. Unions or equally effective fittings shall be provided for all piping connected to the holding tank.

(g) Each holding tank shall be structurally designed to withstand all anticipated earth or other loads. All holding tank covers shall be capable of supporting an earth load of not less than 300 pounds per square foot when the tank is designed for underground installation.

(h) If a holding tank is installed underground the system must be designed so that the tank overflow will gravity drain to the existing sewer line or septic tank. The tank must be protected against sewer line backflow by a backwater valve.

(i) Materials
  1. Holding Tanks shall be steel, protected from corrosion, both externally and internally, by an approved coating or by other acceptable means, shall meet nationally recognized standards for the intended use and shall be approved by the Administrative Authority.
  2. Holding tanks constructed of alternate materials may be approved by the Administrative Authority provided they comply with approved applicable standards.

Section W-10 Valves and Piping. (FIG. 1,2, 3 & 4)

Graywater piping discharging into the holding tank or having a direct connection to the sanitary drain or sewer piping shall be downstream of an approved waterseal type trap(s). If no such trap(s) exists, an approved vented running trap shall be installed upstream of the connection to protect the building from any possible waste or sewer gasses. All graywater piping shall be marked or shall have a continuous tape marked with the words "DANGER - UNSAFE WATER." All valves, including the three-way valve, shall be readily accessible and shall be approved by the Administrative Authority. A backwater valve, installed pursuant to this code, shall be provided on all holding tank drain connections to the sanitary drain or sewer piping.

Section W-11 Irrigation/Disposal Field Construction. (FIG. 5)

(a) Perforated sections shall be a minimum 3-inch diameter and shall be constructed of perforated high density polyethylene pipe, perforated ABS pipe, perforated PVC pipe, or other approved materials, provided that sufficient openings are available for distributio of the graywater into the trench area. Material, construction and perforation of the piping shall be in compliance with the appropriate absorption fields drainage piping standards and shall be approved by the Administrative Authority.

(b) Filter material, clean stone, gravel, slag or similar filter material acceptable to the Administrative Authority, varying in size between 3/4" to 2 1/2" shall be placed in the trench to the depth and grade required by this Section. Perforated section shall be laid on the filter material in an approved manner. The perforated section shall then be covered with filter material to the minimum depth required by this Section. The filter material shall then be covered with untreated building paper, straw or similar porous

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material to prevent closure of voids with earth backfill. No earth backfill shall be placed over the filter material cover until after inspections and acceptance.

(c) Irrigation/disposal fields shall be constructed as follows:

	MINIMUM	MAXIMUM
Number of drain lines per valved zone	1	—
Length of each perforated line	---	100 feet
Bottom width of trench	12 inches	18 inches
Spacing of lines, center to center	4 feet	---
Depth of earth cover of lines	10 inches	---
Depth of filter material cover of lines	2 inches	---
Depth of filter material beneath lines	3 inches	---
Grade of perforated lines	level	3 inches/100 feet

(d) When necessary on sloping ground to prevent excessive line slopes, irrigation/disposal lines shall be stepped. The lines between each horizontal leaching section shall be made with approved watertight joints and installed on natural or unfilled ground.

Section W-12 Special Provisions.

(a) Other collection and distribution systems may be approved by the local Administrative Authority as allowed by Section 201 of the UPC.

(b) Nothing contained in this Appendix shall be construed to prevent the Administrative Authority from requiring compliance with higher requirements than those contained herein, where such higher requirements are essential to maintain a safe and sanitary condition.

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Table W-1 Location of Graywater System.

Minimum Horizontal Distance (in feet) in Clear Required From:	Holding Tank	Irrigation/Disposal Field
Buildings or structures[1]	5 ft[2]	2 ft[3]
Property line adjoining private property	5 ft	5 ft
Water supply wells[4]	50 ft	100 ft
Streams and lakes[4]	50 ft	50 ft[5]
Seepage pits or cesspools	5 ft	5 ft
Disposal field & 100% expansion area	5 ft	4 ft[6]
Septic tank	0 ft	5 ft
On-site domestic water service line	5 ft	5 ft
Pressure public water main	10 ft	10 ft[7]

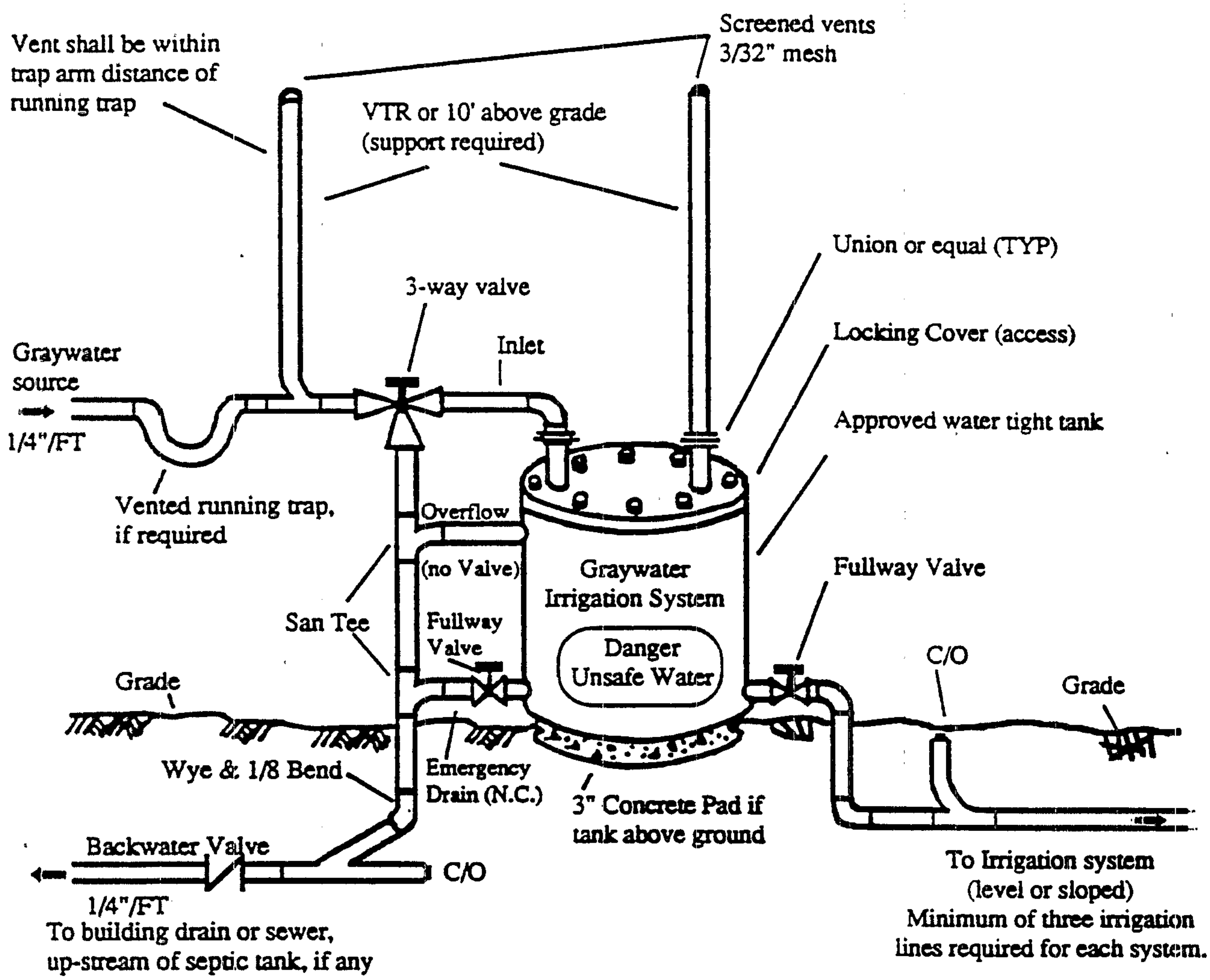
Notes: When irrigation/disposal fields are installed in sloping ground, the minimum horizontal distance between any part of the distribution system and ground surface shall be fifteen (15) feet.

1. Including porches and steps, whether covered or uncovered, breezeways, roofed porte-cocheres, roofed patios, car ports, covered walks, covered driveways and similar structures or appurtenances.
2. The distance may be reduced to zero feet for above ground tanks when first approved by the Administrative Authority.
3. Assumes 45° angle from foundation
4. Where special hazards are involved, the distance required shall be increased as may be directed by the Administrative Authority.
5. These minimum clear horizontal distances shall also apply between irrigation/disposal field and the ocean mean higher high tide line.
6. Plus two (2) feet for each additional foot of depth in excess of one (1) foot below the bottom of the drain line.
7. For parallel construction/for crossings, approval by the Administrative Authority shall be required.

Table W-2 Design Criteria of Six Typical Soils.

Type of Soil	Minimum sq. ft. of leaching/ irrigation area per 100 gallons of estimated graywater discharge per day.	Maximum absorption capacity gals. per sq. ft. of leaching/ irrigation area for a 24-hour period.
1. Coarse sand or gravel	20	5
2. Find sand	25	4
3. Sandy loam	40	2.5
4. Sandy clay	60	1.66
5. Clay with considerable sand or gravel	90	1.10
6. Clay with small amount of sand or gravel	120	0.83

GRAYWATER SYSTEM
Single Tank - Gravity



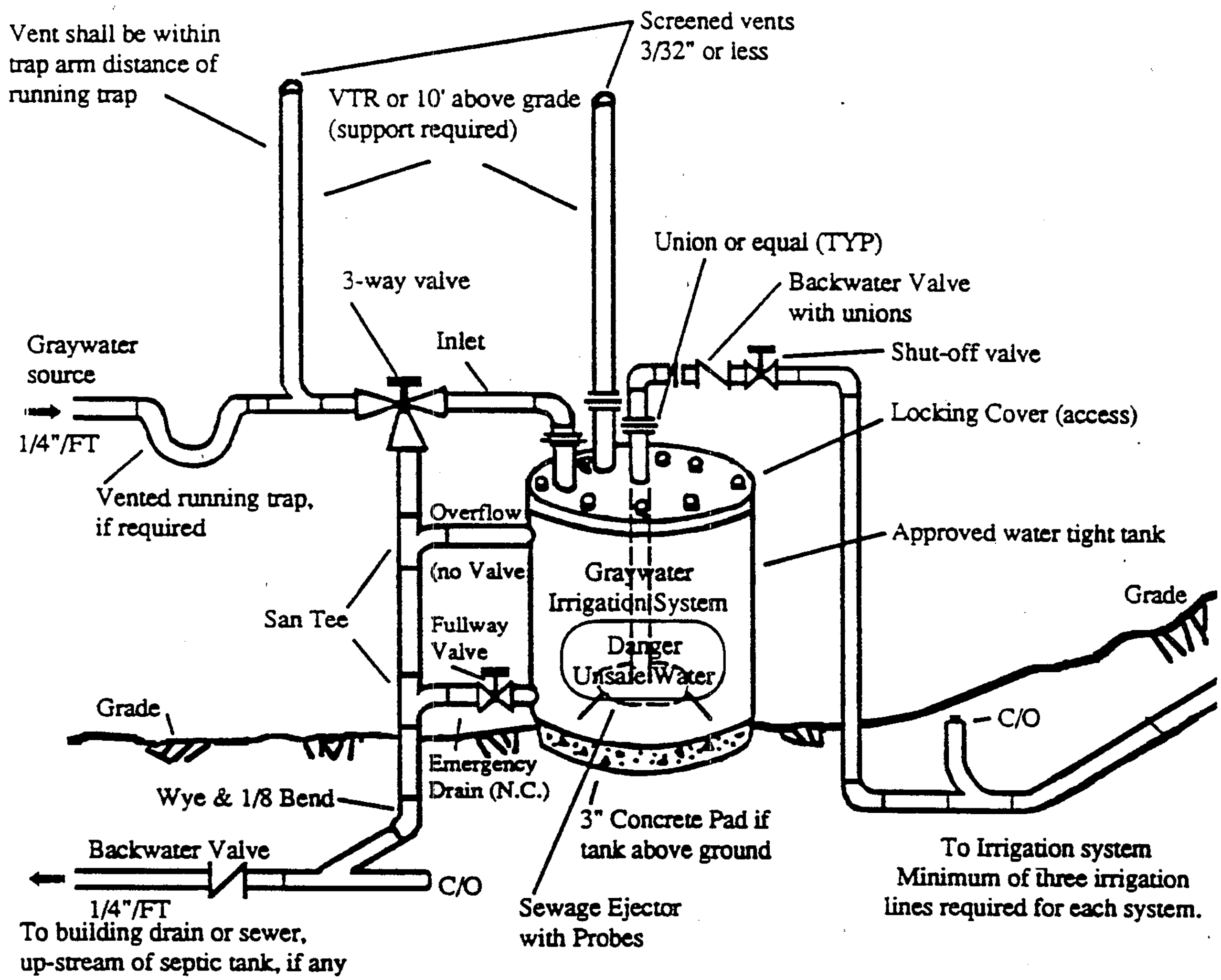
Abbreviations

C/O	Cleanout
N.C.	Normally Closed
VTR	Vent Thru Roof

Uniform Plumbing Code Appendix W	Figure 1
	Date: 2-92 Revised

GRAYWATER SYSTEM

Single Tank - Pumped



Abbreviations

C/O	Cleanout
N.C.	Normally Closed
VTR	Vent Thru Roof

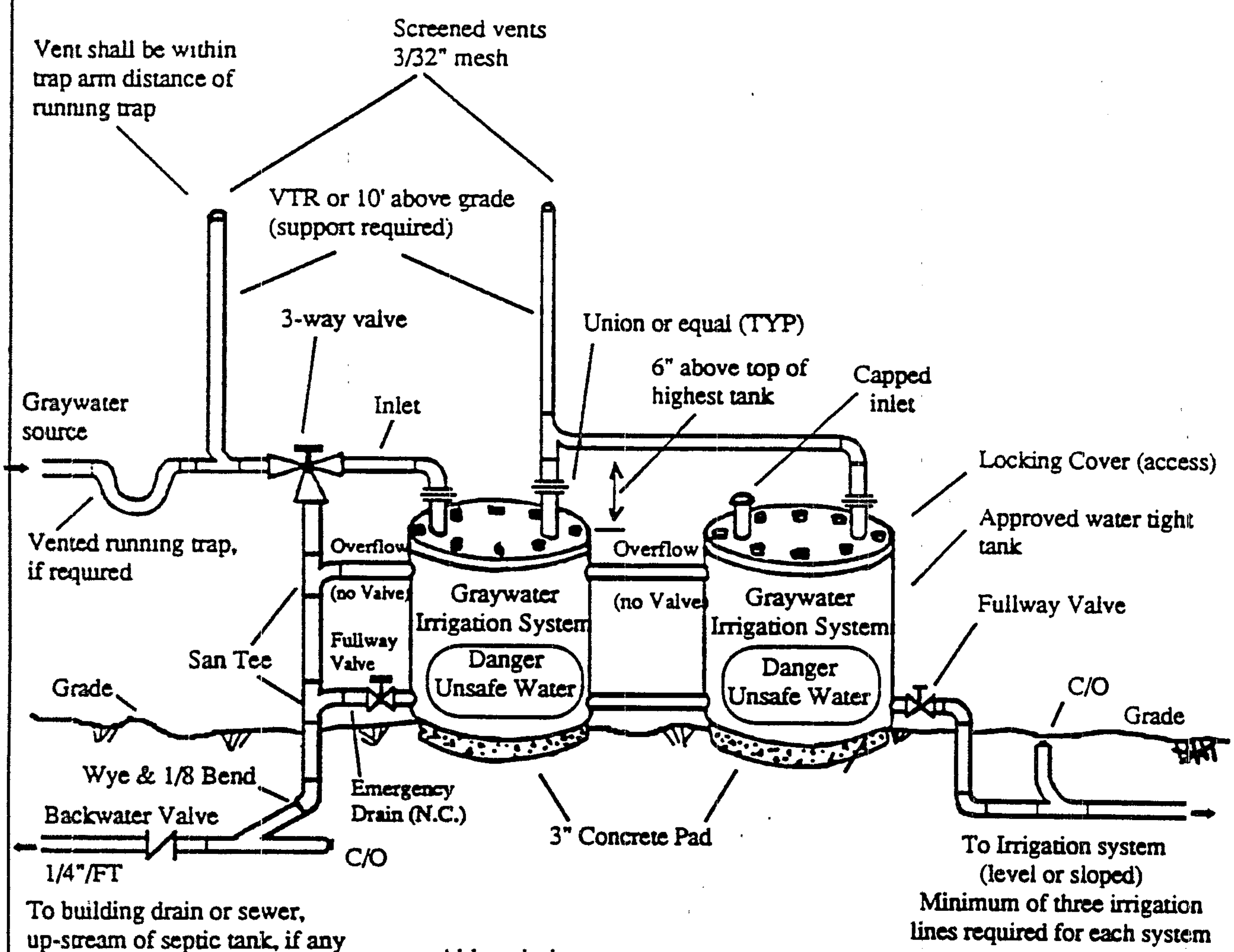
Uniform Plumbing Code
Appendix W

Figure 2

Date: 2-92

Revised

GRAYWATER SYSTEM
Multiple Tank Installation

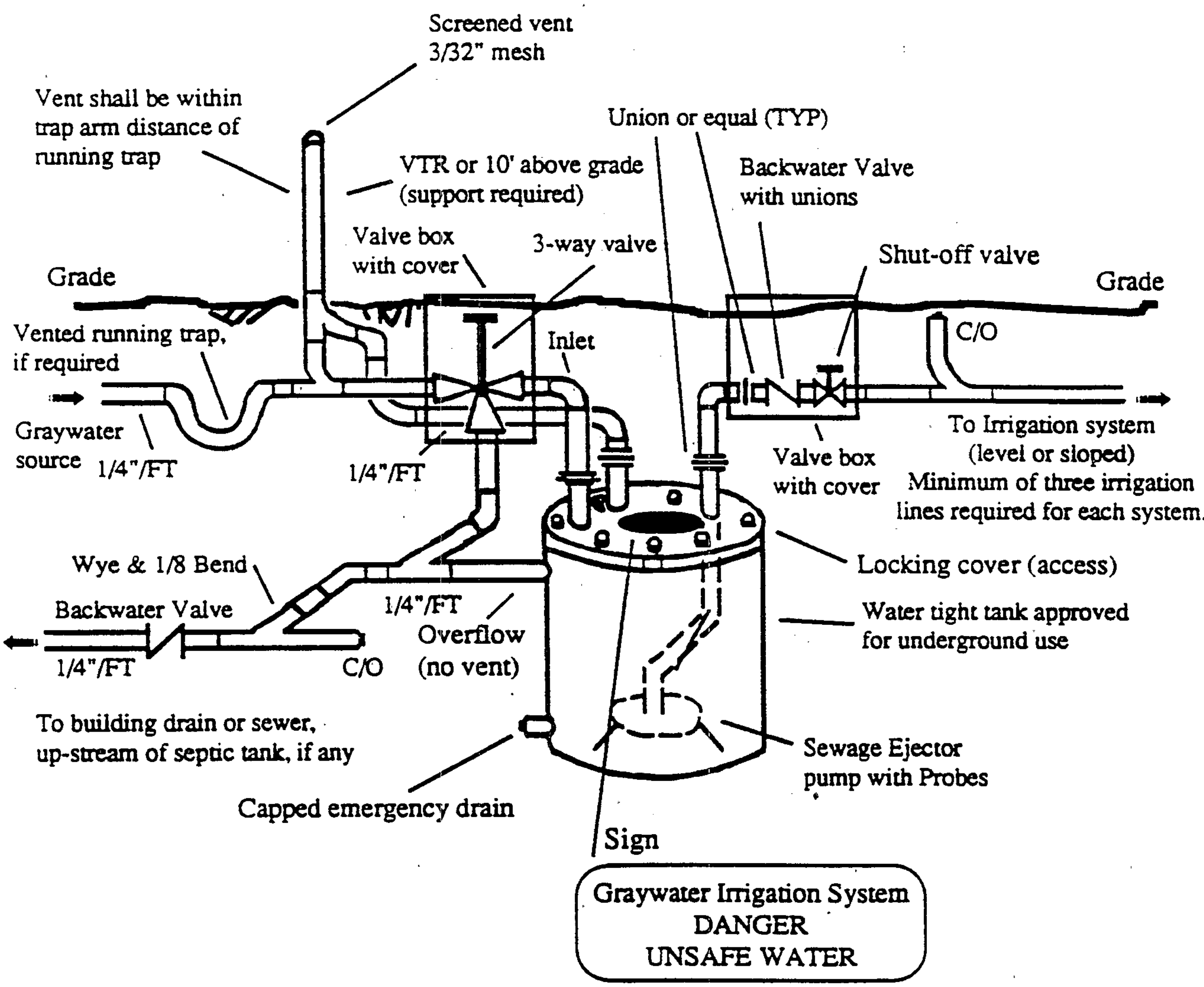


<u>Abbreviations</u>

C/O	Cleanout
N.C.	Normally Closed
VTR	Vent Thru Roof

Uniform Plumbing Code Appendix W	Figure 3
	Date: 2-92 Revised

GRAYWATER SYSTEM
Underground Tank - Pumped



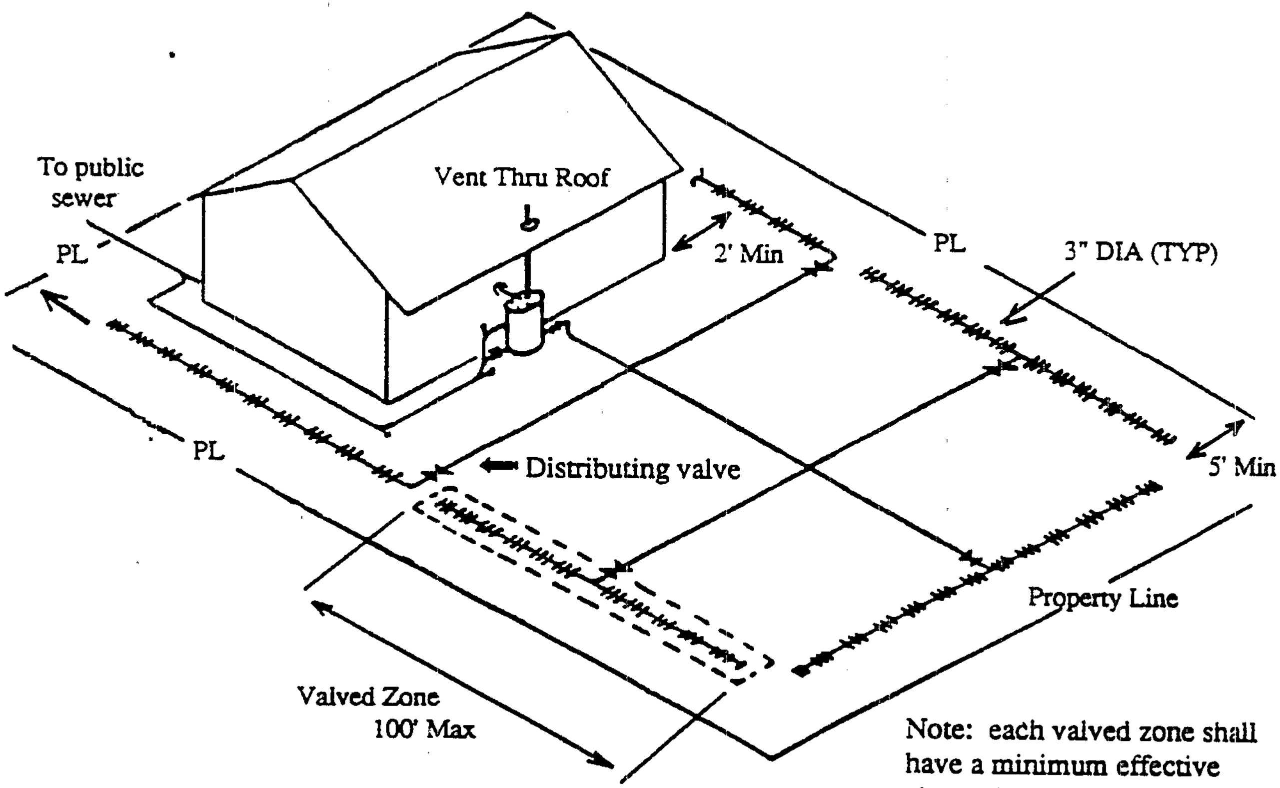
Abbreviations

C/O Cleanout

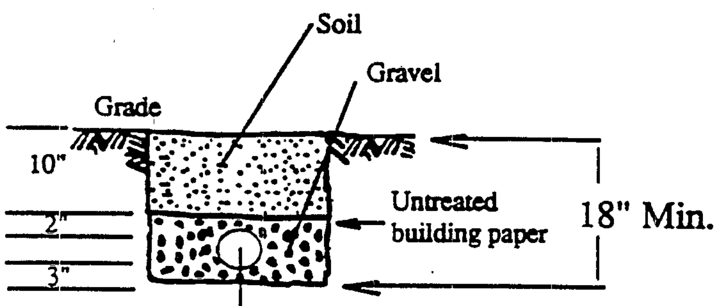
VTR Vent Thru Roof

Uniform Plumbing Code Appendix W	Figure 4
	Date: 2-92 Revised

GRAYWATER SYSTEM
Typical Irrigation Layout



Note: each valved zone shall have a minimum effective absorption/irrigation area in square feet predicated on the estimated graywater discharge in gallons per day and on the type of soil found in the area. Area of the field shall be equal to the aggregate length of perforated pipe sections within the valved zone times the width of the proposed field.



Uniform Plumbing Code Appendix W	Figure 5
	Date: 2-92 Revised

APPENDIX C:
NAPHCC GRAYWATER SURVEY

Please Help Us...

As you might already know, NAPHCC has received a grant from the Environmental Protection Agency (EPA) for a research project that will examine the use of "grey" or recycled water systems. In order to effectively evaluate the use of these systems, research is being conducted and we would like our members to help us in this effort. Using the definitions below, please fill out and return this survey as soon as possible. Thank you, in advance, for your assistance.

Grey Water — ~~Grey~~ water is untreated wastewater which has not come into contact with toilet waste. Grey water includes used water from bathtubs, showers, bathroom wash basins, and water from clothes washing machines and laundry tubs. It does not include waste water from kitchen sinks or dishwashers.

Wastewater Treatment and Recycling System— A wastewater treatment and recycling system recovers wastewater from lavatories, toilets and other wastewater sources within a building, and treats and disinfects wastewater for reuse as flushwater in toilets and urinals. It typically is available as a packaged unit or consists of matching components from a single manufacturer. Its application is predominantly in commercial and institutional buildings.

Name______________________________ Phone______________

City______________________________ State______________

1. Does the current plumbing code in your service territory approve the use of grey water systems and/or wastewater treatment and recycling systems in building? Please check the appropriate spaces below.

   Grey Water Systems ☐ Yes ☐ No
   Wastewater Treatment and Recycling Systems ☐ Yes ☐ No

   If you indicated "yes," what plumbing code has been adopted in your area?

   ____

2. Has the local health department in your service territory approved the use of grey water systems and/or wastewater treatment and recycling systems in buildings? Please check the appropriate spaces below. Use another page if more space is needed

   Grey Water Systems ☐ residential ☐ commercial ☐ institutional ☐ other (describe below)
   Wastewater Treatment/Recycling Systems ☐ residential ☐ commercial ☐ institutional ☐ other

   ____

3. If grey water systems and/or wastewater treatment and recycling systems are approved in your service territory, how are they being utilized? Please check the appropriate spaces below.

   Grey Water Systems ☐ Subsurface ☐ Above Ground
   Wastewater Treatment and Recycling Systems ☐ Subsurface ☐ Above Ground

4. Are there any grey water system and/or wastewater treatment and recycling system installations in your service territory? Please provide the following information on each installation. Use another page if more space is needed.

Grey Water Systems	Wastewater Treatment and Recycling Systems
Name of Installation	Name of Installation
Name of Contact	Name of Contact
Phone #	Phone #
1.____________________	1.____________________
2.____________________	2.____________________
3.____________________	3.____________________

(Continued on reverse side)

5. Are you familiar with any manufacturers/distributors of grey water systems and/or wastewater treatment and recycling systems? Please provide the name of each manufacturer/ distributor, name of contact and phone number. Use another page if more space is needed.

Grey Water Systems	Wastewater Treatment and Recycling Systems
Manufacturer/Distributor Name of Contact Phone #	Manufacturer/Distributor Name of Contact Phone #
______________________	______________________
______________________	______________________
______________________	______________________

6. Are you familiar with any studies that have evaluated health and safety aspects or economics of grey water systems or wastewater treatment and recycling systems? Please provide the following information on each study. Use another page if more space is needed.

☐ Yes ☐ No

If yes, who is sponosor of study,

Sponsor/Contact/Telephone________________________

Sponsor/Contact/Telephone________________________

Sponsor/Contact/Telephone________________________

7. Are dual plumbing systems being installed in your service territory for any of the following types of buildings?

☐ single family residential buildings
☐ multifamily buildings
☐ office buildings
☐ other buildings or facilities (please describe)

____

____

8. What do you estimate is the average cost of installing (including plumbing modifications, equipment and controls) a grey water system or a wastewater treatment and recycling system in the following types of buildings?

Grey Water Systems

$________ single family/residential building
$________ multifamily buildings
$________ office buildings

Wastewater Treatment and Recycling Systems

$________ single family/residential building
$________ multifamily buildings
$________ office buildings

Please return this survey to:
NAPHCC Grey Water Survey, P.O. Box 6808, Falls Church, VA 22040 or
Fax: 1 (703) 237-7442