Cartwright Consulting Co.

www.cartwright-consulting.com
pscartwright@msn.com

United States Office
8324 16th Avenue South
Minneapolis, MN 55425-1742
Phone: (952) 854-4911
Fax: (952) 854-6964

European Office
President Kennedylaan 94
2343 GT Oegstgeest
The Netherlands
Phone: 31-71-5154417
Fax: 31-71-5156636

Graywater Recovery & Reuse

Presented at:

2013 ASPE Technical Symposium

by

Peter S. Cartwright, PE

September 20, 2013

INTRODUCTION

Our world is not running out of water, but it is running out of readily accessible acceptable potable water.

Over the years, treatment technologies have been developed. Pumping, storage and distribution infrastructures have been designed and constructed. Regulations have been crafted to protect the health of the consumer and the integrity of the system.

Unfortunately, our municipal water infrastructure is in sad shape. Many, if not most, treatment plants are undersized and in a state of disrepair. Some of the U.S. water distribution systems are 100 years old. The FDA estimates that $384 billion in improvements are needed through 2030 to continue supplying safe drinking water for the nation's current population of 300 million.

Based on the requirement to provide all households with high quality water meeting the latest Safe Drinking Water Standards, it makes no difference that less than 2% of this water is actually consumed. The water entering the residence is used once and then discharged to the sewer or septic system.

Likewise, our plumbing systems are currently designed to deliver only potable water to every usage point and collect and discharge the wastewater from those points through one piping system to the sewer or septic tank.

So, the bottom line is that the one line bringing in our drinking water also supplies the water for all the rest of our indoor water activities: flushing toilets, showering, bathing, washing hands and clothes, etc. These do not demand the same quality of water as for drinking and culinary activities.

If we divide our water usage activities into two categories:

Those which generate wastewater containing high concentrations of BOD (biochemical oxygen demand) – "Blackwater" and those that don't – "Graywater." We can classify our fixtures as follows:

Blackwater	Graywater
Toilet/urinal	Bath/Shower
Kitchen sink	Lavatory sink
Dishwasher	Washing machine
Disposer	

DOMESTIC RESIDENTIAL SOURCES

1998 Census data indicate that the average U.S. household size is 2.7 people, and an AWWA study determined the median daily per capita flow rate to be 54 to 67 gallons/day (204 to 253 liters/day) for residential applications.

If we use a figure of 60 gpd/person, the profile of all indoor household wastewater generation per person per day is summarized in the table below.

Water Source	Gallons/person/day
Laundry	13.0
Bath	1.0
Shower	10.2
Handwashing	9.5
Toilet Flushing	16.2
Dishwasher	0.8
Leakage	8.3
Other	1.0

TYPICAL GRAYWATER SOURCES

Although the specific chemical parameters in this graywater result from the particular incoming water source (as well as from chemicals introduced during the activities), and can vary considerably from one household to another, the table below indicates the ranges of significant contaminants.

Parameter	Unit	Range
BOD_5 (Biochemical Oxygen Demand)	mg/L	60-300
TSS (Total Suspended Solids)	mg/L	30-185
E.Coli (Bacteria)	cfu*/100 ml	80-30,000
Fecal Coliform (Bacteria)	cfu*/100 ml	50-100,000
P_{total} (Phosphorus)	mg/L	1-15
N_{total} (Nitrogen)	mg/L	4-30
pH (Acidity/Alkalinity)	units	5-10

**Colony Forming Units*

By comparison, whereas blackwater contaminant concentrations for most parameters are close to those of graywater, the bacterial concentrations of blackwater are easily 100 to 1,000 times greater than those of graywater.

Whereas all water supplies contain contaminants which are brought into the home by the incoming water, the plethora of chemicals we put into water are too numerous to count. In addition to soaps, detergents, fabric softeners and other products used during domestic activities, even more contaminants are introduced from hands, faces, bodies and fabrics.

The following table lists typical sources of graywater chemical contaminants and concentrations.

Ingredient	Concentration (mg/L)
Sunscreen	1500
Moisturizer	1000
Toothpaste	3250
Deodorant	1000
Na_2SO_4 (Sodium sulfate)	3500
$NaHCO_3$ (Sodium bicarbonate)	2500
Na_3PO_4 (Trisodium phosphate)	3900
Clay	5000
Vegetable Oil	700
Shampoo or Hand Soap	7200
Laundry Detergent	15000
Boric Acid	140
Lactic Acid	2800

One survey indicated that normal household products contain more than 2500 chemicals.

NON-RESIDENTIAL SOURCES

Given that graywater is generated as a result of human activity, there should be little difference between residential and non-residential graywater quality; however, the relative quantities of graywater produced vary considerably as a function of the facility. Following is a table listing total water usage by building type.

Non-Residential Water Usage by Building Type

	Hospitals	Schools	Hotels	Office Buildings	Restaurants
Landscape Irrigation	10%	38%	21%	10%	3%
Restrooms, Showers	30%	43%	23%	39%	30%
Laundry	5%	3%	10%	—	—
Cleaning, Sanitation	5%	1%	12%	—	2%
Cooling, HVAC	30%	4%	5%	37%	2%
Kitchen	5%	6%	15%	2%	50%
Miscellaneous	15%	5%	14%	12%	13%

Extracted from MCERF, "Water-Efficience Technologies for Mechanical Contractors: New Business Opportunities", Figure 1.

From the above, it is apparent that graywater could be reused in most of these water usage areas.

The leading U.S. standards development and testing organization in the area of water and wastewater treatment and distribution is NSF International.

They have developed 2 new product standards addressing graywater: NSF 350 and NSF 350-1, which establish design and performance requirements for treatment systems for wastewater from both residential and commercial facilities.

NSF/ANSI Standard 350 can be applied to only graywater as defined earlier or to combined graywater and blackwater. NSF/ANSI Standard 350-1 applies to subsurface discharge only, whereas Standard 350 addresses surface irrigation, toilet/urinal flushing and similar nonpotable applications.

Both standards define residential applications as wastewater flows up to 1500 gpd and commercial as generating flows exceeding 1500 gpd.

Commercial laundries are not categorized by flow rates.

The following tables summarizes these standards.

NSF/ANSI Standard 350: On-site Residential and Commercial Water Reuse Treatment Systems	
Building Types	Residential, up to 1,500 gallons per day Commercial, more than 1,500 gallons per day and all capacities of commercial laundry water
Influent Types	Combined black and graywater Graywater Bathing water only Laundry water only
Effluent Uses	Nonpotable applications, such as surface and subsurface irrigation and toilet and urinal flushing
Ratings	Two classifications that vary slightly in effluent quality: • Class R: single-family residential • Class C: multifamily and commercial Systems are further described based on the type of influent (combined, graywater, bathing only, laundry only).

Source:
Tom Bruursema
Plumbing Systems & Design
October 2011

NSF/ANSI Standard 350-1: On-site Residential and Commercial Graywater Treatment Systems for Subsurface Discharge	
Building Types	Residential, up to 1,500 gallons per day Commercial, more than 1,500 gallons per day and all capacities of commercial laundry water
Influent Types	Combined black and graywater Graywater Bathing water only Laundry water only
Effluent Uses	Subsurface irrigation only
Ratings	Single effluent quality with no classifications Systems are further described based on the type of influent (graywater, bathing only, laundry only).

Source:
Tom Bruursema
Plumbing Systems & Design
October 2011

For graywater reuse applications, in addition to individual residences, the standards apply to such commercial applications as:

- Lodging facilities
- Business parks
- Schools
- Shopping establishments
- Public buildings without food processing or manufacturing operations

They also apply to laundry facilities for hospitals, hotels, rental uniforms, etc., where the wastewater may contain large amounts of soil and high strength cleaners.

The standards include requirements for:

- Water tightness
- Noise levels
- Access ports
- Monitoring
- Bypass
- Product literature
- Performance evaluation

TESTING REQUIREMENTS – RESIDENTIAL SYSTEMS

Both Standards 350 and 350-1 require 26 weeks of continuous testing with regularly scheduled sampling at a frequency of three days per week.

The following table lists the graywater challenge test water analysis:

Parameter	Range
TSS (Total Suspended Solids)	80-160 mg/L
BOD_5 (Biochemical Oxygen Demand)	130-180 mg/L
Temperature	25-30°C
pH (Acidity/Alkalinity)	6.5-8 units
Turbidity	50-100 NTU
P_{total} (Phosphorus)	1-3 mg/L
N_{total} (Nitrogen)	3-5 mg/L
COD (Chemical Oxygen Demand)	250-400 mg/L
TOC (Total Organic Carbon)	50-100 mg/L
Total Coliform (Bacteria)	10^3-10^4 cfu/100 mL
E.coli (Bacteria)	10^3-10^4 cfu/100 mL

The challenge water is generated from normal household constituents mixed into tap water with hardness in the range of 110-220 mg/L (as $CaCO_3$) and alkalinity greater than 40 mg/L (as $CaCO_3$).

Depending upon the intended application against which the system is to be tested (bathing, laundry, combined graywater), the challenge water is to be prepared from following components:

Bathing Source Water

Wastewater Component	Amount/100 L
Body wash with moisturizer	30 g
Toothpaste	3 g
Deodorant	2 g
Shampoo	19 g
Conditioner	21 g
Lactic Acid	3 g
Secondary effluent	2 L
Bath cleaner	10 g
Liquid hand soap	23 g
Test dust	10g

The 30 day average concentration of the bathing water delivered to the system shall be as follows:

Parameter	Required Range
TSS (Total Suspended Solids)	50-100 mg/L
BOD_5 (Biochemical Oxygen Demand)	100-180 mg/L
Temperature	25-35°C
pH (Acidity/Alkalinity)	6.0-7.5 units
Turbidity	30-70 NTU
P_{total} (Phosphorus)	1.0-4.0 mg/L
N_{total} (Nitrogen)	3.0-5.0mg/L
COD (Chemical Oxygen Demand)	200-400 mg/L
TOC (Total Organic Carbon)	30-60 mg/L
Total Coliform (Bacteria)	10^3-10^4 cfu/100 mL
E.coli (Bacteria)	10^2-10^3 cfu/100 mL

Laundry Source Water

Wastewater Component	Amount/100 L
Liquid detergent (2X)	40 mL
Test dust	10 g
Secondary effluent	2 L
Liquid laundry fabric softener	21 mL
Na_2SO_4	4 g
$NaHCO_3$	2 g
Na_3PO_4	4 g

The 30 day average concentration of the laundry water deliver to the system shall be as follows:

Parameter	Required Range
TSS (Total Suspended Solids)	50-100 mg/L
BOD_5 (Biochemical Oxygen Demand)	220-300 mg/L
Temperature	25-35°C
pH (Acidity/Alkalinity)	7.0-8.5 units
Turbidity	50-90 NTU
P_{total} (Phosphorus)	<2 mg/L
N_{total} (Nitrogen)	4.0-6.0 mg/L
COD (Chemical Oxygen Demand)	300-500 mg/L
TOC (Total Organic Carbon)	50-100 mg/L
Total Coliform (Bacteria)	10^3-10^4 cfu/100 mL
E.coli (Bacteria)	10^2-10^3 cfu/100 mL

<u>Bathing and Laundry Source Waters Combined</u>

Each 100 L challenge water shall be prepared using 53 L of bathing and 47 L laundry challenge waters. The 30 day average concentration of the graywater delivered to the system shall be as follows:

Parameter	Range
TSS (Total Suspended Solids)	80-160 mg/L
BOD_5 (Biochemical Oxygen Demand)	130-180 mg/L
Temperature	25-30°C
pH (Acidity/Alkalinity)	6.5-8.0 units
Turbidity	50-100 NTU
P_{total} (Phosphorus)	1-3 mg/L
N_{total} (Nitrogen)	3-5 mg/L
COD (Chemical Oxygen Demand)	250-400 mg/L
TOC (Total Organic Carbon)	50-100 mg/L
Total Coliform (Bacteria)	10^3-10^4 cfu/100 mL
E.coli (Bacteria)	10^2-10^3 cfu/100 mL

HYDRAULIC LOADING AND SCHEDULES

During the minimum 6 month (26 weeks) testing and evaluation period, the system shall be subjected to periods of design loading, followed by stress loading, and then additional weeks of design loading. Class R and Class C systems claiming service intervals of greater than 6 months shall be loaded beginning in week 27 at design loading, according to the time frame and % rated daily hydraulic capacity as shown below, and shall continue dosing such that the test period equals the prescribed service interval.

Loading of the systems will be based on the following matrix:

System Design	Design loading					Stress test				
	First 16 weeks	First 20 weeks	Last 4 weeks	Last 3.5 weeks	Last 2.5 weeks	Wash-day surge	Power/equip-ment failure	Vacation	Water efficiency	Cleaning solution
R-Bathing only	X			X			X	X	X	
R-Laundry only	X				X	X	X	X	X	
R-Combined	X				X	X	X	X	X	
C-Bathing only		X	X				X	X		
C-Laundry only		X	X				X	X		
C-Combined		X	X				X	X		X

Addition of cleaning solution during final 4.5 week of test

Stress events indicate typical events in a residence that affect treatment performance. These include clothes washing activities, increased hydraulic loadings to simulate working-parent events, power failure events and vacations.

Extreme stress conditions (overfeeding of corrosive cleaners, excessive hydraulic overloading, other conditions that deviate from the manufacturer's recommendations) are not included in the testing.

TESTING REQUIREMENTS – COMMERCIAL SYSTEMS

For systems designed to treat graywater from any source generating more than 1500 gpd, and from commercial laundry establishments producing wastewater of any capacity, testing is performed on the actual wastewater under field conditions.

The sampling and testing is performed under the same protocol as residential treatment systems.

EFFLUENT REQUIREMENTS

The treated effluent must meet the criteria as listed below for both residential and commercial systems:

Summary of effluent criteria for individual classifications

Measure	Class R		Class C	
	Test Average	Single Sample Maximum	Test Average	Single Sample Maximum
TSS (Total Suspended Solids) mg/L	10	30	10	30
BOD_5 (Biochemical Oxygen Demand) mg/L	10	25	10	25
Turbidity NTU	5	10	2	5
E.coli[2] (Bacteria) MPN/100 mL	14	240	2.2	200
pH (Acidity/Alkalinity) SU	6.0-9.0	NA[1]	6.0-9.0	NA
Storage Vessel Disinfection mg/L	$\geq$ 0.5 - $\leq$ 2.5			
Color	MR[3]	NA	MR	NA
Odor	Non-offensive	NA	Non-offensive	NA
Oily Film and Foam	Non-detectable	Non-detectable	Non-detectable	Non-detectable
Energy Consumption	MR	NA	MR	NA
SAR	MR	MR	MR	MR

[1] NA not calculated

[2] Calculated as geometric mean

[3] MR measured and reported only

REGULATIONS

As expected, state regulations addressing graywater reuse are highly variable, and only 12 states have listed requirements to date. The USEPA has guidelines, as well as NOWRA (National Onsite Wastewater Recycling Association).

A summary of these regulations, including those proposed, drafted and interim, are in the Appendix.

Regarding the acceptance of NSF350 by code-setting bodies, it is currently referenced in the following:

IAPMO Green Plumbing and Mechanical Code Supplement
International Construction Code
2015 International Plumbing Code (not yet published, but the language is finalized)

And is currently proposed in:

2015 International Residential Code

2015 Uniform Plumbing Code

TREATMENT TECHNOLOGIES

For graywater to be reused, it almost always requires some treatment. The choice of technologies is usually dictated by these factors:

- Graywater quality
- Specific use of treated water
- Volume requirement

The key is to have an arsenal of technologies available to efficiently remove hazardous or undesirable contaminants from the supply. There is no single technology that will sufficiently and economically remove all classes of contaminants; however, there are treatment technologies that, collectively, are capable of effectively reducing the concentration of virtually any contaminant down to acceptable levels for any water reuse equipment, or to meet any quality requirement.

Water-borne contaminants can be classified as follows:

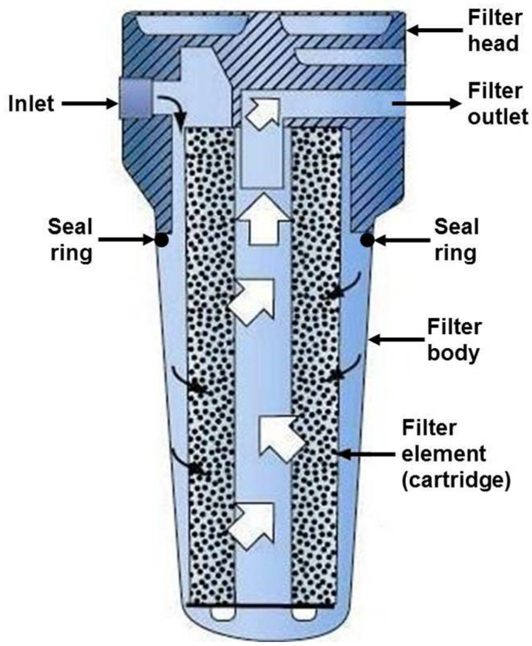
Class	Examples
Suspended solids	Dirt, clay, colloidal materials, silt, dust, insoluble metal oxides and hydroxides
Dissolved organics	Trihalomethanes, synthetic organic chemicals, humic acids, fulvic acids
Dissolved ionics (salts)	Heavy metals, silica, arsenic, nitrate, chlorides, sulfates
Microorganisms	Bacteria, viruses, protozoan cysts, fungi, algae, molds, yeast cells
Gases	Hydrogen sulfide, methane, radon, carbon dioxide

Numerous technology choices are available for removing the above contaminants, and the more common ones are listed below.

I) Suspended solids removal

Cartridge Filters – cartridge filters are replaceable "inserts", usually cylindrical in configuration, that are inserted into housings, and are typically replaced when they have captured so much suspended solids that the pressure drop across the housing becomes unacceptable (usually above 10 psig). Offered in many different designs and micron removal ratings (down into the submicron range), they provide an excellent array of choices to the knowledgeable design engineer. They are typically used at flow rates less than 5 gpm.

Following is an illustration of a typical filter cartridge/housing unit:



Cartridge Filter/Housing

Media Bed Filters – These consist of a tank containing granular media such as sand, anthracite, garnet, etc., which capture suspended solids and retain them inside the bed until it is taken off line and backwashed. These bed filters are typically capable of removing suspended solids down to 10-20 microns in size, and are normally used at flow rates in the 5 to 20 gpm range. Media filters are backwashed to remove captured particles.

A typical media bed filter is illustrated below.

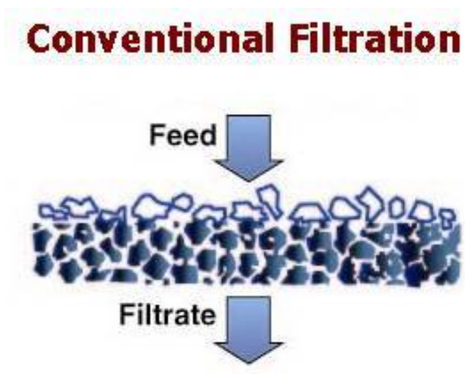
Media Bed Filter

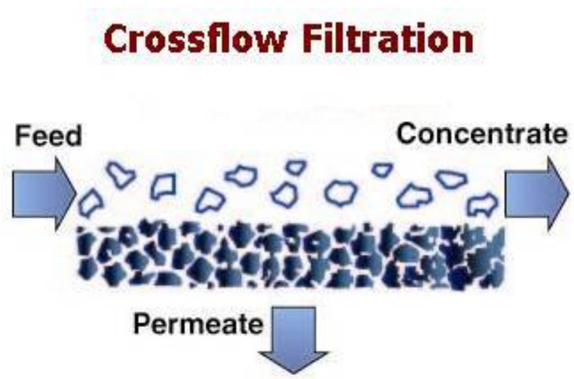
Carbon and Ceramic Block Filters - These are similar in design to cartridge filters. The advantage of the carbon block cartridge is that it also performs the adsorptive function of activated carbon, described later. Ceramic cartridges can be cleaned and reused. Granular activated carbon can be utilized as medium in a media bed filter also.

Microfiltration - It is one of the four pressure-driven membrane technologies that are best explained as a group, below.

Membrane technologies are based on a process known as “crossflow” filtration, which allows for continuous treatment of liquid streams. In this process, the bulk solution flows over and parallel to the membrane surface, and because the system is pressurized, water is forced through the membrane and becomes "permeate". The turbulent flow of the bulk solution over the surface minimizes the accumulation of particulate matter.

The four major pressure-driven crossflow membrane technologies in use today are microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO), and all utilize pressure as the driving force. These technologies behave differently than filters in that (with some exceptions) the feed stream is continuously pumped at a high flow rate across the surface of the filter media (membrane), with a portion of this stream forced through the membrane to effect separation of the contaminants, producing the permeate. The concentrated contaminant remaining in the other stream (concentrate) exits the membrane element on a continuous basis. Because the concentrate stream is continuously removing contaminants, these technologies require only occasional backwashing or cleaning. Conventional and crossflow filtration are illustrated below.





Conventional vs. Crossflow Filtration

Microfiltration is the membrane technology designed for suspended solids removal, and there are systems available to remove particulate contaminants down into the submicron range, including bacteria. They are capable of operating at virtually all flow rates.

II) Dissolved organics removal

Activated carbon adsorption utilizes a specially prepared granular carbon medium capable of adsorbing dissolved organic contaminants and certain gases. It is very effective in removing many taste and odor contaminants, including chlorine, and is usually installed in housings similar to media or cartridge filters. The activated carbon material normally requires replacement once or twice per year.

Special resin adsorbents are also available for organics removal. They are designed for a particular removal function, such as humic acids, and require occasional regeneration and/or replacement.

Ultrafiltration is another membrane technology, with smaller pores than MF, capable of removing dissolved organics. Instead of adsorbing the contaminants, it is continuously removing them in the concentrate stream.

III) Dissolved salts removal

Most graywater contains relatively high concentrations of salts, both from the incoming water supply, as well as soluble contaminants resulting from activities within the facility. These can include both benign and potentially hazardous compounds. The most practical technology for salts reduction is reverse osmosis (or possibly nanofiltration), another of the membrane technologies. These technologies are often designed to operate at a single tap (point-of-use - POU). POU RO systems are very commonly used throughout the U.S. today.

IV) Disinfection

It is important to understand that neither ozone nor UV impart a residual disinfectant to the water. This is an important consideration when water must be stored for any length of time. Whereas a chlorine residual is recommended in private buildings, such as a home, it is important to remember that it is generally mandated for applications in public buildings.

This author's preference would be to ozonate the water entering the storage tank followed by feeding a low concentration of liquid bleach (sodium hypochlorite) to maintain a residual of 0.3-0.5 mg/L free chlorine. In this approach, the ozone will inactivate the majority of microorganisms, and the chlorine will minimize bacterial regrowth in the storage tank and distribution system. Activated carbon adsorption can be utilized at the point-of-use for chlorine removal.

Ozone will inactivate all microorganisms much more effectively than chlorine, and will also break down dissolved organic molecules to a certain extent, allowing activated carbon adsorption to be more effective.

Many experts favor a multi-barrier approach wherein disinfection may be utilized in conjunction with a separate technology such as ultrafiltration.

V) Gases

In general, graywater does not contain objectionable gases. On the other hand, bacterial action in the stored water may produce gases such as hydrogen sulfide that are both unpleasant and dangerous. This speaks to the value of rigorous microbial inactivation.

Activated carbon adsorption is usually effective in removing these gases.

TREATMENT SUMMARY

The selection of treatment technologies in any graywater reuse application is dictated by the following factors:

- Ultimate use of the recovered graywater.
- Specific contaminants in the graywater to be reduced.
- Total volume requirements.
- Regulations.

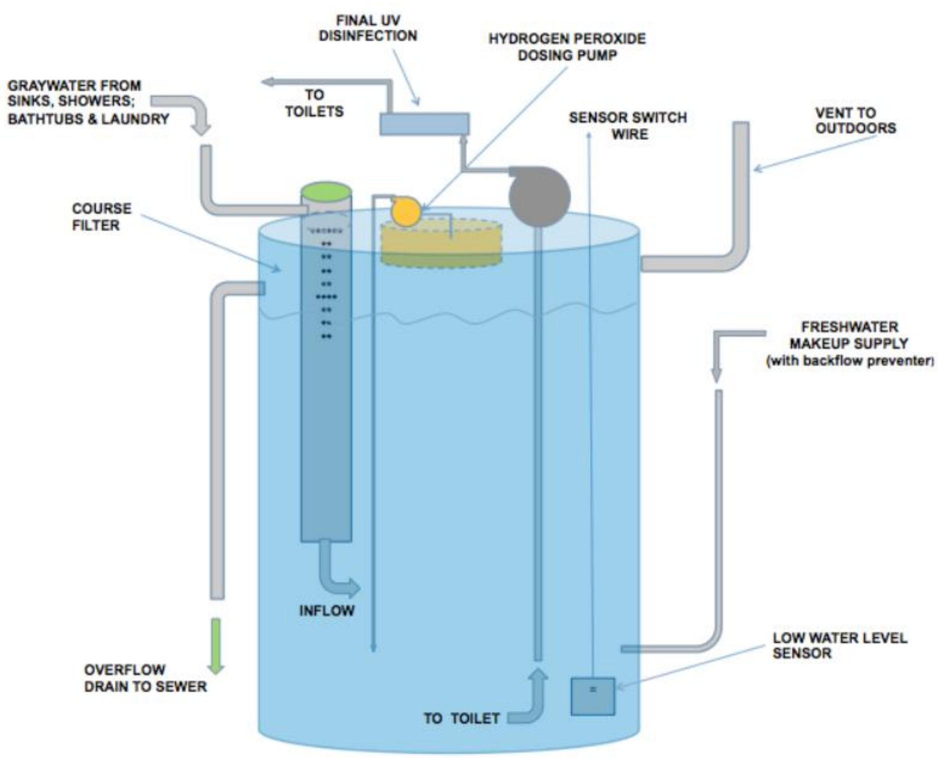
EXAMPLE SYSTEM

A Master's Thesis prepared by Brock Hodgson at Colorado State University, Fort Collins, CO evaluated the design requirements for a system treating graywater collected from showers and lavatory sinks from a number of units at a residence hall at the university. The treated water was to be used for toilet flushing.

The investigation included media filtration, cartridge filtration followed by disinfection. Both the sand filtration (20-40µ) and 100µ cartridge filtration effectively reduced TSS (total suspended solids) concentration.

For disinfection, the researcher evaluated UV (ultraviolet) with H_2O_2 (hydrogen peroxide), chlorine (sodium hypochlorite) only, UV with chlorine residual and ozone with chlorine residual. In terms of cost and efficacy, chlorine (sodium hypochlorite) performed the best, with almost complete inactivation of E.coli and total coliform bacteria.

A photograph and illustration of this system are below:

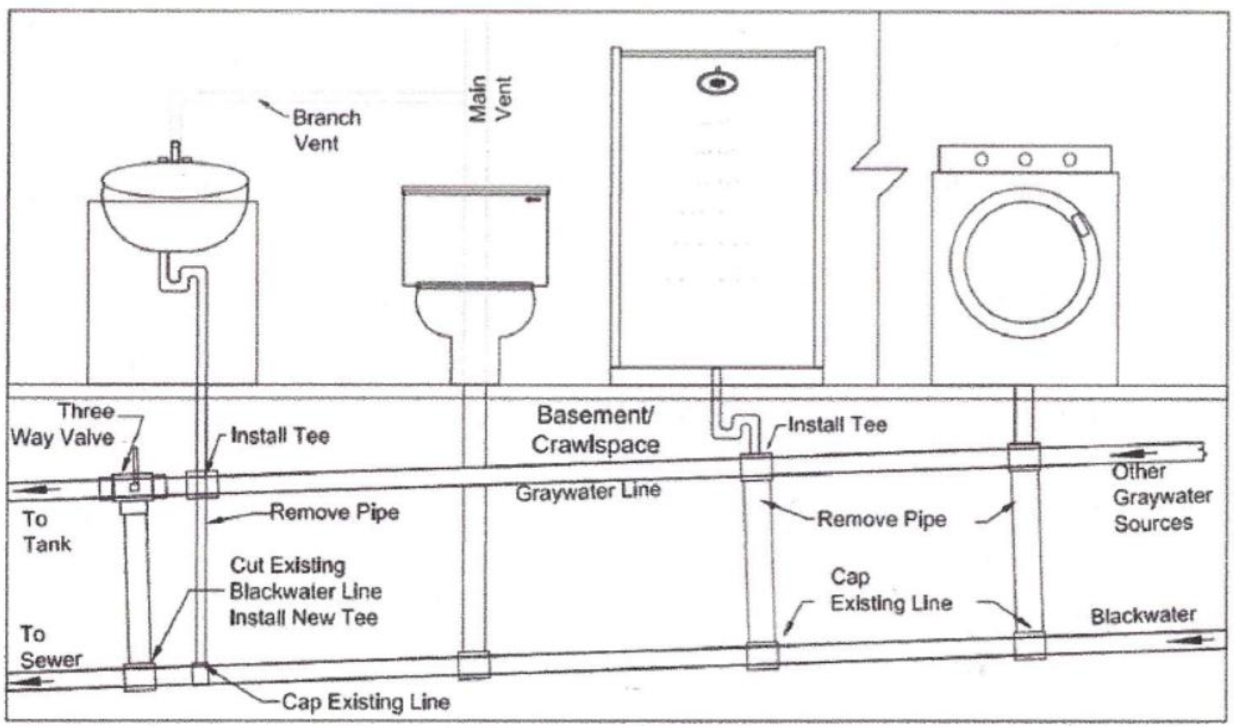

FINAL UV
DISINFECTION
HYDROGEN PEROXIDE
DOSING PUMP
GRAYWATER FROM
SINKS, SHOWERS;
BATHTUBS & LAUNDRY
TO
TOILETS
SENSOR SWITCH
WIRE
VENT TO
OUTDOORS
COURSE
FILTER
FRESHWATER
MAKEUP SUPPLY
(with backflow preventer)
INFLOW
LOW WATER LEVEL
SENSOR
OVERFLOW
DRAIN TO SEWER
TO TOILET

SYSTEM DESIGNS

The Urban Water Center at Colorado State University has significant expertise in graywater treatment system design and application of treated graywater.

They recommend that its use be confined to toilet flushing and outdoor irrigation. Those uses alone can reduce potable water demand in a residence by as much as 50%.

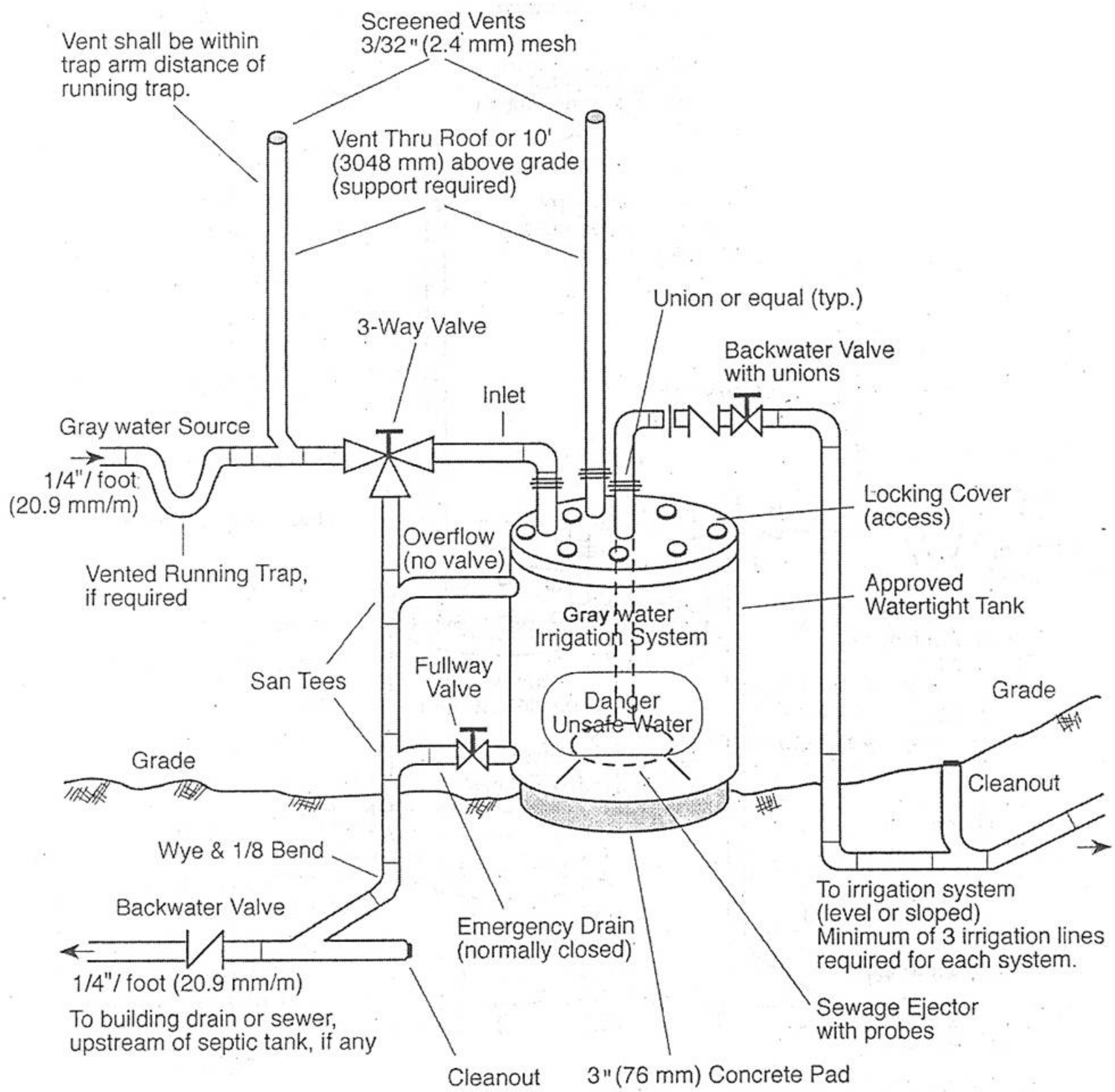
They offer the following retrofit design to separate and collect graywater from sinks, shower and washing machines:



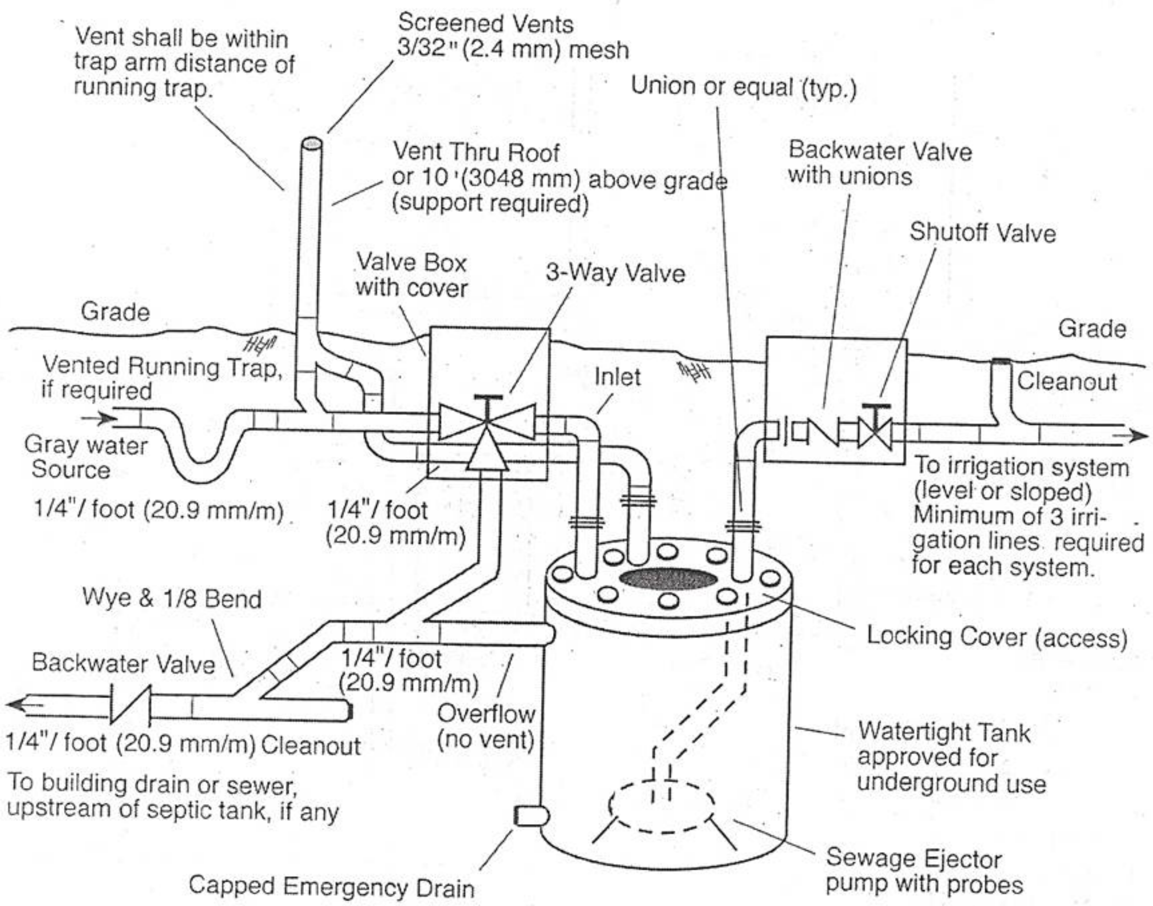
Regarding outdoor irrigation, they recommend that the graywater be applied through subsurface or drip irrigation (no surface exposure).

WERF (Water Environment Research Foundation) sponsored a study on the effect of graywater application on landscape plants over a five year period in the southwest U.S. Out of 22 plant species studied, only 3 (avocado, lemon and Scotch pine) showed any negative response from graywater irrigation. Those responses included reduced growth, leaf burning and a small reduction in fruit production.

The following illustrations are from "Graywater Guide" published by the California Department of Water Resources, and depict surface mounted and underground storage tanks, including pumps and piping:



Graywater System Surface Mounted Tank – Pumped (conceptual)



Graywater System Underground Tank – Pumped (conceptual)

CONCLUSIONS

There is no doubt that the concept of graywater recovery and reuse is here to stay, and will surely become a viable water conservation option in the future.

As regulators acknowledge the many benefits of graywater reuse and mandate quality requirements for specific uses, the opportunities will grow rapidly.

It is important that we understand the technical details associated with graywater, and become proficient in the treatment technologies and system design requirements to take advantage of these opportunities.

APPENDIX

n	Toilet/Urinal Flushing	Laundry Uses	Car Washing	BOD	TSS	Turbidity	Bacterial	Cl Residual	TKN	TN	TP	pH	Other / Comments
	Yes		Yes			< 2 NTU, max of < 5 NTU	< 1 FC CFU/100 mL median (no detectable FC in four of last seven daily samples); max <23. < 200 FC CFU/100 mL median (in four of the last seven daily samples); max < 800.			< 10 mg/L < 10 mg/L			Irrigation of food crops, recreational impoundments, residential, school ground, open access landscape irrigation, toilet/urinal flushing, fire protection systems, spray irrigation of orchards or vineyards, commercial closed-loop air conditioning, vehicle and equipment washing, snow making. Surface irrigation of orchards and vineyards, golf course and restricted access landscape irrigation, landscape impoundment and dust control.
	Yes	Yes	Yes			≤ average of 2 NTU & ≤ 5 NTU 95% in 24-hours; 10 NTU max	≤ 2.2 MPN/100 mL (median TC for last 7 days; shall not exceed 23/100 mL more than once for last 30 day period; not exceed 240/100 mL)	continuous monitoring at the plant; provide CT (total residual x modal contact time measured at the same point) ≥ 450 mg-min/L at all times with modal contact time ≥ 90 min					Food crops, including all edible root crops, where the recycled water comes into contact with the edible portion of the crop. Parks and playgrounds, school yards, residential landscaping, unrestricted access golf course, and unrestricted access impoundments (recreational ponds/lakes). There are additionsl requirements for body contact impoundments. Flushing toilets and urinals, priming drain traps, industrial process water that may come into contact with workers, structural fire fighting, decorative fountains, commercial laundries, artificial snow making for commercial outdoor use and commercial car washes. There is a whole class of other uses in which there is minimal public contact expected where disinfected secondary is allowed (also a distinction is made between secondary 2.2 TC and 23 TC)
s	Yes			≤ 20 mg/L CBOD	≤ 5 mg/L	≤ 5 NTU	75% below detection; max ≤25 MPN/100 mL FC.	≥ 1 mg/L 15 minute Cl resid					Fire protection, construction dust control and aesthetic purposes.
			Yes	≤ 5 mg/L	≤ 5 mg/L	< 2 NTU (95%)	≤ 23 CFU/100 mL FC median; monthly geo mean.	Detect - 15 min Cl resid				6 to 9	Irrigation of golf course, playground parks.
	Yes	Yes					(a) disinfection combined with filtration to inactivate or remove 99.999% of plaque-forming units of MS2 or polio virus; and (b) ≤ 2.2/100 mL FC median of last 7 days; ≤ 23/100 mL in no more than one sample in 30 day period; no sample >200/100 mL. ≤ 2.2/100 mL FC median density of ≤ 23/100 mL of the last 7 days; no more than one sample in 30 day period >200/100 mL. No state requirements.						Covers a wide range of uses including irrigation of food crops where recycled water contacts the edible portion of the crop, including all root crops; parks, elementary schoolyards, athletic fields and landscape around some residential property; non-edible vegetation in areas with limited public exposure; ornamental plants for commercial use; above ground food crops not contacted by irrigation. Includes commercial and public laundries, decorative fountains, and washing yards, lot and driveways. "Oxidized wastewater" means wastewater in which the organic matter has been stabilized, is nonputrescible, and contains dissolved oxygen. Above ground irrigation with buffer for non-edible vegetation in areas with limited public exposure, and ornamental plants for commercial use. Underground with buffer only for parks, elementary schoolyards, athletic fields and landscape around some residential property; underground only for above ground food crops. Underground only for .
	Yes			≤ 10 mg/L median; ≤ 20 mg/L maximum	≤ 10 mg/L median; ≤ 20 mg/L maximum (measured prior to disinfection)	≤2 NTU median; ≤5 NTU maximum (as alt to TSS).(measured prior to disinfection).	E. coli (CFU/100 mL) - median ND, maximum ≤200; Thermotolerant coliform (CFU/100 mL) - median ND, maximum ≤200	≥ 0.5 mg/L totl chlorine residual, measured at point where treated eff leaves reservoir or storage.					Median value of at least five samples collected over a 30-day period.
				≤ 10 mg/L	≤ 5 mg/L	≤ 2 NTU	< 1 CFU/100 mL FC, median; running count over last 7 days; not to exceed 14/100 mL.	≥ 1 mg/L 30 minute Cl resid		≤ 10 mg/L		6 - 9 (90%)	Irrigation uses include golf course, landscape projects.
	Yes			< 30 mg/L	<10 mg/L	< 5 NTU	< 100 CFU/100 mL FC, median; from last 7 days.	Detected		< 10 mg/L	Monitor 2 times per month.	6 - 9 (90%)	

		Yes		≤ 5 mg/L	≤ 2 NTU	< 2.2 CFU/100 mL FC, median over 7 days; max ≤14 in any sample	≥ 10 mg/L 15 minute Cl resid	≤ 10 mg/L		UV dose 100 mJ/cm^2. Irrigation uses include golf course, playground or park; hydroseeding.
						≤ 30 day long mean of 126 E. coli/100 mL and 406 E. coli/100 mL in any single sample.				Irrigation of firewood, ornamental nursery stock, Christmas trees, sod or pasture for animals.
						≤ 23 TC/100 mL based on last 7 days; and 240 TC/100 mL in any two consecutive samples.				Irrigation of firewood, ornamental nursery stock, Christmas trees, sod or pasture for animals; processed food crops; orchards or vineyards if applied directly to soil; landscape irrigation of golf courses, cemeteries, or industrial or business campuses. Some industrial, commercial or construction uses. Water supply for landscape impoundments.
	Yes					≤ 2 TC/100 mL based on last 7 days; and < 23 TC/100 mL in any single sample.				Same uses as Class C, plus: non-residential toilet or urinal flushing, floor drain trap priming. Water supply source for restricted recreational impoundments.
	Yes	Yes			Before disinfec-tion, ≤ 2 NTU within 24 hr period; 5 NTU >5% of time within 24 hr period; <10 NTU at any time.	After disinfection, median of ≤ 2 TC/100 mL based on last 7 days; and < 23 TC/100 mL in any single sample.				Same uses as Class B, plus: Irrigation for any agricultural or horticultural use; landscape irrigation of parks, playgrounds, school yards, residential landscapes or other landscapes accessible to the public. Commercial car washing or fountains when the water is not intended for human consumption. Water supply source for nonrestricted recreational impoundments. Artificial groundwater recharge by surface infiltration or subsurface injection.
	Yes		≤ 5 mg/L		≤ 3 NTU	≤ 20 CFU/100 mL FC median, ≤ 75 max.				Residential and landscaping, parks, golf courses, school yards and athletic fields.
			≤ 20 mg/L		≤ 5 NTU	≤ 200 CFU/100 FC median, in 4 of last 7 samples; max ≤ 800.				Where public is not present during irrigation activities or would not come into contact with reclaimed water.
e ts	Yes		≤ 30 mg/L	≤ 30 mg/L	≤ 2 NTU, ≤ 5 NTU max, continuous monitoring	≤ 20 CFU/100 mL FC median				Irrigation - food crops and non-food crops, landscape irrigation both restricted and open access areas; Impoundments; Restricted and unrestricted recreational; Fish hatchery basins, fountains, flushing of sewers, street cleaning, washing, dust control; Firefighting and protection.
			≤ 30 mg/L	≤ 35 mg/L		< 200 fecal coliform CFU/100 mL				Also have limit of ≤ 15 mg/L oil and grease.
			≤ 10 mg/L	< 60 mg/L ≤ 5 mg/L						Also have limit of < 15 mg/L oil and grease.
			≤ 10 mg/L	≤ 5 mg/L		No detectable fecal coliform	≥ 1 and ≤ 10 mg/L free Cl resid		6 to 9	Surface irrigation except food crops, vehicle washing, toilet and urinal flushing, clothes washing, air conditioning, soil compaction, dust control, washing aggregate and making concrete.
			≤ 30 mg/L	≤ 30 mg/L		< 200 fecoliform CFU/100 mL	≥ 1 and ≤ 10 mg/L free Cl resid		6 to 9	
	Yes	Yes	≤ 10 mg/L		≤ 2 NTU	< 1 FC CFU/100 mL median (for last 7 days; should not exceed 14/100 mL for any single sample)	≥ 1 mg/L 30 minute Cl resid			Unrestricted urban reuse (parks, playgrounds, school yards, residences, toilet flushing air conditioning, fire protection, construction, ornamental fountains and aesthetic impoundments. All types of landscape irrigation (golf courses) vehicle washing, toilet flushing, fire protection commercial air conditioning); Ag reuse on food crops (surface or spray irrigation of any food crop, including crops eaten raw); Unrestricted recreational reuse (impoundment of water in which no limitations are imposed on body-contact water recreation activities)
	Yes		< 30 mg/L	< 30 mg/L	< 5 NTU	< 200 CFU/100 mL median value for E coli; maximum < 800 CFU/100 mL for E coli.	> 1 mg/L after 30 minutes		6 to 9	