An Education on Growing Water Scarcity and The Benefits of Domestic Greywater Recycling Systems

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Bachelor of Science

by

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EXECUTIVE SUMMARY

Water scarcity is becoming an ever growing concern in the world today. Fresh potable water is a natural resource which is being used more rapidly than it is being replenished. A growing global population, agriculture, and industry have placed great demands on our water resources. There is a need to help conserve our planet's fresh water reserves. A tremendous percentage of household drinking water in the United States is currently being used to flush toilets, water yards and wash laundry or dishes. A practice termed 'greywater recycling' allows a person to utilize slightly used water to irrigate landscapes and flush away waste. This practice began centuries ago in arid lands where water and rainfall were scarce. Greywater recycling in now being seen in certain areas of the United States, but there is a greater need for education on this topic. Homeowners will find that through greywater recycling, they can save money and fresh water resources simultaneously.

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SECTION 1: A PURPOSE AND NEED FOR GREYWATER RECYCLING

Part I: Water as a Natural Resource

Introduction

Water conservation and recycling have been topics of discussion for many years. A relatively new form of recycling is that of waste water or greywater. The demand for water is growing while fresh water is becoming scarce. As scientists and governments work to find solutions to our planet's needs for clean water, the general public can be doing their part as well. Conserving water on a completely voluntary and personal level is one way in which we can make small changes that could possibly have a large impact. Greywater recycling in the home is a conservation tool that could potentially aid this problem. There are systems that range from simple to complex. The individual can base their method on whatever best fits their lifestyle and budget. In many parts of the world there are people already implementing this practice with a fair amount of success. It is important to note that drinking water, or potable water, is water that can be consumed without any risk of short or long term harm. In most developed countries, the water supplied to households, businesses, and industry, is indeed potable water. Only a fraction of this water is being consumed or used in food preparation. Most of it is being used on clothes washing, showering, flushing, and landscaping. Education on water scarcity, the increasing demand for water, and the potential savings with greywater recycling, may be a key factor in the water conservation effort.

Water as a Renewable Resource

A non-renewable resource is a raw material or energy source which is consumed faster than nature can replace it. Fossil fuels like coal and petroleum, types of nuclear power, and underground fresh water aquifers are good examples. The Energy Information Administration (EIA) defines a renewable resource as, "Fuels that can be easily made or 'renewed'." They further explain that, "a non-renewable resource is a natural resource

which cannot be produced, grown, generated, or used on a scale which can sustain its consumption rate. Once the resource is depleted there is no more available for future needs."[1] Although fresh water is considered a renewable resource, the world's supply of clean, fresh water is steadily declining. Water demands are already exceeding supply in many parts of the world. As the world's population continues to rise, so will the demand.[2]

Fresh water should be considered one of our finite resources on Earth. A renewable resource needs to be managed so the supply does not completely run out. A good example of a renewable resource is timber. We have a finite amount of trees on earth. If we were to harvest them all at once, it would take many years to regrow new trees. Fresh water is very much the same in this regard. The United States Environmental Protection Agency (USEPA) has a partnership program termed *WaterSense* which tells us that, "While it is true that the water cycle is continuously returning water to the Earth, it is not always being returned to the same place, or in the same quantity or quality."[3] Greywater recycling is a way in which people can aid in conserving some of our supply of available fresh water. To further support these ideas Bliss (2012) states:

> "People tend to have the misconception that a resource's status of renewability means that it is then an endless resource. A renewable resource should not be considered endless. Water continually moves around the earth, with each climate receiving its own type and volume of precipitation. If a community happens to overuse their water supply, the source may temporarily run out, but it is believed that it will come back with time. A method of renewing or replenishing a resource is through conservation. If a local drought takes hold of an area, water conservation efforts can help replenish the reservoirs and may eventually eliminate the drought."[4]

Distribution of Earth's Water

Ninety-seven percent of all the water on the Earth is in the form of salt water. Only three percent of water on the planet is fresh water. Slightly over two-thirds of this fresh water is unavailable to us as it is frozen in glaciers and polar ice caps. The remaining unfrozen fresh water is found mainly in aquifers or groundwater. Only 0.22% of fresh water is considered unavailable as atmospheric water, or water that is found in the air.[5]

Sources of Freshwater

Surface water

Surface water can be defined as any fresh water found in a river, lake, or wetland.[6] Our planet's supply of surface water is renewed when it is replenished by precipitation. Our fresh water can also be lost through precipitation. It is lost when rain falls over saline oceans. Fresh water can quickly be lost through evaporation, evapotranspiration, and sub-surface seepage. More is taken from our supply as our fresh water rivers and streams flow out into oceans. Furthermore "human and agricultural activities can have a large and often devastating impact on surface water when it is diverted or consumed in large quantities (Wikipedia 2012)."[7] Surface water accounts for 1.3 percent of our world's fresh water. This illustration is shown in Figure 1 and was adapted from Shiklomanov (1993). Oceans account for 96.5% of our total water on the planet. Fresh water is only 2.5% of that total.

Aquifers and groundwater

Sub-surface water, or groundwater, is defined as fresh water located in the pore space of soil and rocks. It can also be classified as water flowing within an aquifer below the water table.[8] As defined by Wikipedia, "An aquifer is a wet underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, or silt) from which groundwater can be usefully extracted using a well."[9] Aquifers can occur at varying depths. Those closer to the surface are more likely to be used for water supply and/or irrigation. They are also more likely to be recharged by rainfall.

Fresh-water aquifers are often over-exploited and may draw in non-potable water or salt water which can leave them tainted. Aquifers are critically important in human habitation and agriculture.[10] Many villages and large cities throughout the world draw their water supply from wells and aquifers. Thirty point one percent of our world's fresh water is groundwater.

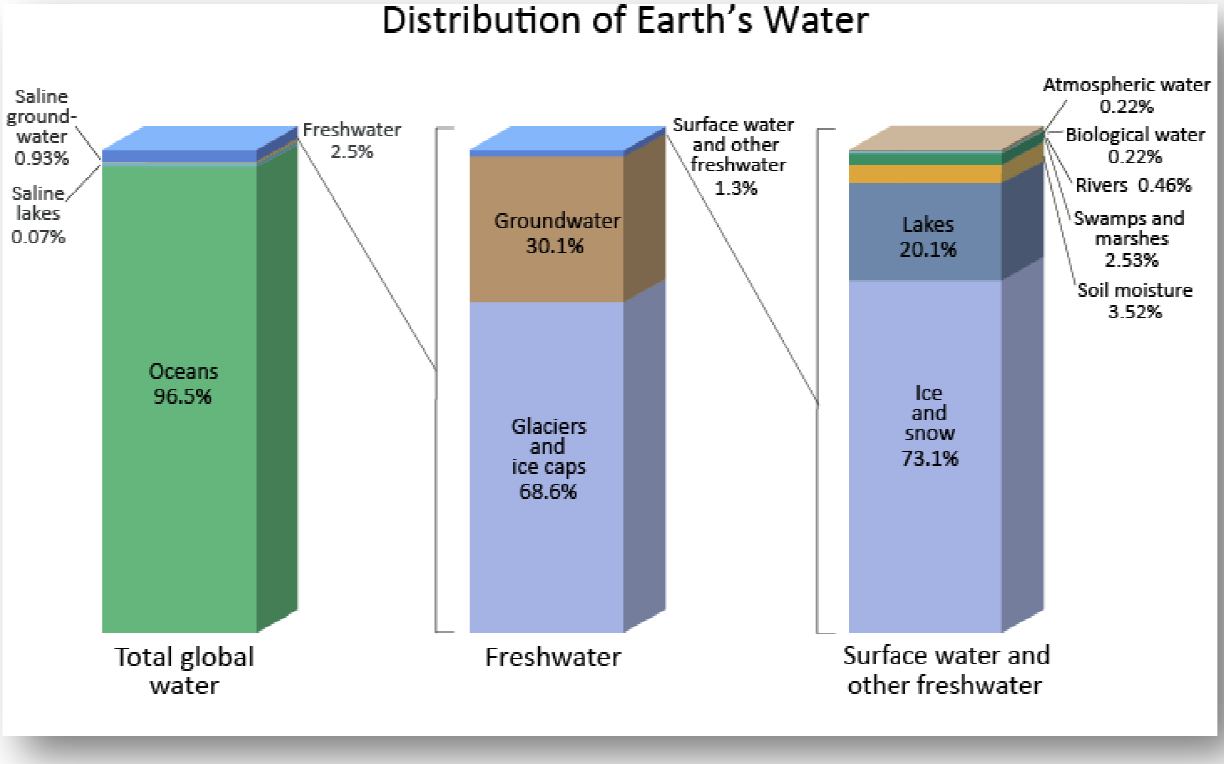


FIGURE 1. Distribution of Earth's Water. Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H Gleick's (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources.

Part II: Uses of Freshwater

Uses of freshwater are categorized as consumptive and non-consumptive. A use of water is considered consumptive if that water is not immediately available for another use. We see this in the example of farming and evaporation. Once that water is used to irrigate crops, it cannot be further utilized. Once water is evaporated we cannot retrieve it. Water that can actually be treated and returned as surface water is generally considered non-consumptive. It is non-potable but still usable. It can be put to further use in another way.[11] Greywater recycling and waste water recycling is the reuse of non-consumptive water.

Household

It is estimated that 8% of worldwide water use is for household purposes.[12] These would include drinking water, water for cooking, bathing, sanitizing, clothes washing and gardening. Basic household requirements have been estimated by the United States Environmental Protection Agency (EPA). They say that Americans are using large quantities of water. They further state that the average family of four can use up to 400 gallons of water every day with 70% being used inside the home. The following illustration seen in Figure 2, from the United States Geological Service (2005), shows in some states a potentially larger number of gallons used per person. In some areas we see the average being 151-200 gallons per person per day. This would mean that a family of 4 could potentially consume 600-800 gallons in one day on average.

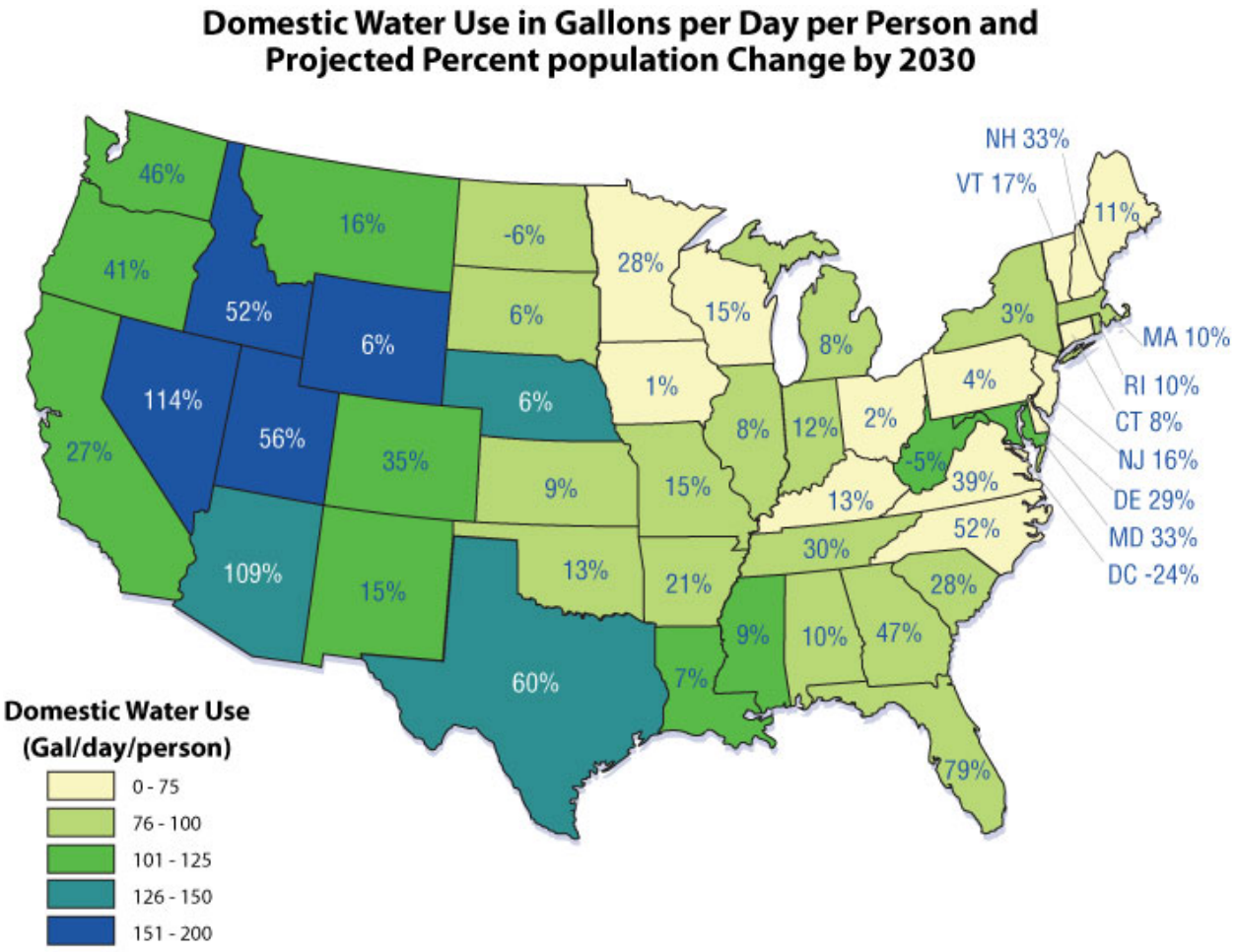


FIGURE 2. Domestic Water Use in Gallons per Day per Person and Projected Percent Population Change by 2030.

Source: USGS (2005).

Agricultural

Agriculture is a major component of fresh water consumption. It is estimated that 69% of worldwide water use is for irrigation, with 15-35% of irrigation withdrawals being unsustainable.[13] It takes around 800 gallons of water, converted from liquid to vapor, to produce enough food to satisfy just one person's daily dietary needs. This is a considerable amount when compared to water required for drinking, which is less than 2 gallons. To produce food for the over 7 billion people who inhabit the planet today, it is estimated we would need enough water to fill a canal 10 meters deep, 100 meters wide and 7,100,000 kilometers long. This is enough to circle the globe 180 times.[14]

Industrial

Studies have calculated that 22% of worldwide water use is industrial.[15] This includes fresh and salt water. In the United States according to the United States Geological Service (USGS), the total usage of freshwater for industrial purposes in 2005 was 5% with 41.5 % going towards thermoelectric power needs, as shown in Figure 3. The major industrial users are hydroelectric dams, thermoelectric power plants, which use water for cooling, ore and oil refineries, which use water in chemical processes, and manufacturing plants, which use water as a solvent.[16]

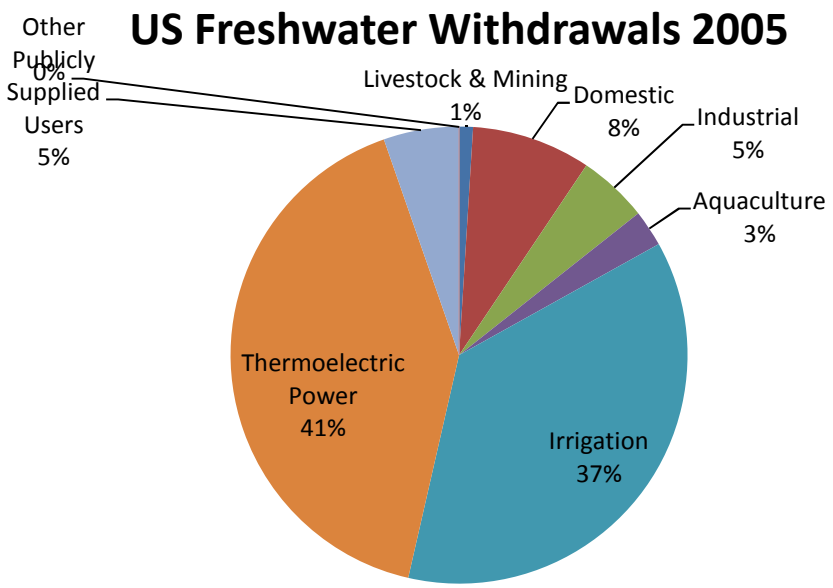


FIGURE 3. US Freshwater Withdrawals 2005. Water data from the USGS Circular 1344: Estimated Use of Water in the United States in 2005 by Joan F. Kenny, Nancy L. Barber, Susan S. Hutson, Kristin S, Linsey, John K Lovelace, and Molly A Maupin.

Recreation

Recreational water use is becoming a need for concern as well. Although it is small in comparison, it is a growing percentage of total water usage.[17] Recreational water use is mostly tied to our reservoirs. The usage is usually termed non-consumptive. Examples of recreational uses are boating, fishing, swimming, white water rafting, and water skiing or wake boarding. The people who frequent these places are the non-consumptive users. Upon closer review of Figure 4 one can see that the chart illustrates the amount of water we use while recreating near lakes and resorts. Mangers of water resources must always take this usage into account when planning. Recreational usage may also reduce the availability of water at certain times of the year. For example if water is held in a reservoir so it is available for public use in the summer, it may not be available to the farmers during that time.

TABLE 1. Recreational Water Use-Typical Flow

RECREATIONAL WATER USE **Typical Flow Rates**[a]

Facility	Unit	Flow/Gallons/Unit/Day		Flow/Liters/Unit/Day	
		Range	Typical	Range	Typical
Apartment, Resort	Person	50 - 70	60	190 - 280	230
Bowling Alley	Alley	150 - 250	200	270 - 950	780
Cabin, Resort	Person	8 - 50	40	80 - 190	150
Cafeteria	Customer	1 - 3	2	4 - 11	8
Cafeteria	Employee	8 - 12	10	30 - 45	38
Camp (pioneer type)	Person	15 - 30	25	57 - 110	95
Camp (children's w/toilet, bath)	Person	35 - 50	45	130 - 190	170
Camp (day w/meals)	Person	10 - 20	15	38 - 76	57
Camp (day w/o meals)	Person	10 - 15	13	38 - 57	49
Camp (luxury, private bath)	Person	75 - 100	90	280 - 380	340
Camp (trailer camp)	Trailer	75 - 150	125	280 - 570	470
Campground (developed)	Person	20 - 40	30	76 - 150	110
Cocktail Lounge	Customer	12 - 25	20	45 - 95	76
Coffee Shop	Customer	4 - 8	6	15 - 30	23
Coffee Shop	Employee	8 - 12	10	30 - 45	38
Country Club	Guest	60 - 130	100	230 - 490	380
Country Club	Onsite Employee	10 - 15	13	38 - 57	49
Dining Hall	Meal Served	4 - 10	7	15 - 38	28
Dormatory, Bunkhouse	Person	20 - 50	40	76 - 190	150
Fairground	Visitor	1 - 2	2	4 - 8	8
Hotel, Resort	Person	40 - 60	50	150 - 230	190
Picnic Park (flush toilets)	Visitor	5 - 10	8	19 - 38	30
Store, Resort	Customer	1 - 4	3	4 - 15	11
Store, Resort	Employee	8 - 12	10	30 - 45	38
Swimming Pool	Customer	5 - 12	10	19 - 45	38
Swimming Pool	Employee	8 - 12	10	30 - 45	38
Theater	Seat	2 - 4	3	8 - 15	11
Visitor Center	Visitor	4 - 8	5	15 - 30	19

Source: United States Environmental Protection Agency. 1998. Establishing treatment system performance requirements. Risk Management Research. Report no. EPA/625/R-00/008-Chapter 3.

Environmental

Environmental water usage today is a very small and growing percentage as well. This may include water stored in impoundments and released for environmental purposes. It more often involves, "Water that is retained in public waterways through regulatory limits of abstraction (National Water Commission 2010)."[18] Environmental water usage includes water disbursed onto natural or artificial wetlands. This includes any artificial lakes intended to create wildlife habitat, fish ladders, and water released from reservoirs timed to help fish spawn. This also includes water that is used to restore natural flow regimes.[19] This practice is considered non-consumptive.

Part III: Increasing Water Scarcity

Increasing water scarcity worldwide is due in large part to growing human populations, the need for irrigation in agriculture, climatic changes, depletion of groundwater and aquifers, pollution and urbanization. Increasing water scarcity from the reasons listed above can lead to consequences on a local or community level as well. The EPA has a partnership with a program that is called *Water Sense*. In a fact sheet published by them they state that, "Strains on water supplies and our aging water treatment systems can lead to a variety of consequences for communities:

- Higher water prices to ensure continued access to a reliable and safe supply
- Increased summer watering restrictions to manage shortages
- Seasonal loss of recreational areas like lakes and rivers when the human demand for water conflicts with environmental needs
- Expensive water treatment projects to transport and store freshwater when local demand overcomes available capacity."[20]

Human Populations Worldwide

In 60% of European cities with more than 100,000 people, groundwater is being used at a faster rate than it can be replenished.[21] In 2000 the world's population was 6.2 billion. The United Nations estimates that by the year 2050 there will be an additional 3.5 billion people, with most of the growth coming out of developing third-world countries that already are suffering from water scarcity.[22] Water demand will therefore increase unless we implement corresponding increases in water conservation and water recycling efforts.[23]

Agriculture

According to the USDA's Economic Research Service, agriculture is the major user of groundwater and surface water in the United States. In fact they estimate that agriculture accounts for 80% of the consumptive use. They believe it is closer to 90% in some of the drier western states.[24]

To look at things on a global level, in 2007 the International Water Management Institute of Sri Lanka conducted an assessment of water management in agriculture to see if the world had enough fresh water to provide food for its growing population.[25] It assessed the availability of water for agriculture on a global scale. They mapped out locations suffering from water scarcity and found that a fifth of the world's people live in areas crippled with water shortages. One third of the world does not even have access to potable water, which equates to 2.3 billion people. The report found that it would be possible to produce the food required in coming years, but that continuation of the current food production, coupled with environmental trends, would lead to a water crisis in many parts of the world. To avoid this impending global water crisis, farmers will have to strive to increase productivity to meet growing demands. At the same time industries and cities will have to find ways to use their water more efficiently.[26]

Climate change

According to The World Bank, 2009 "Water and Climate Change: Understanding the Risks and Making Climate-Smart Investment Decisions" climate change will have significant impacts on water resources around the world because of the close connections seen between our regional climates and the hydrological cycle. A brief sketch of the water cycle is shown in Figure 4.[27] Rising temperatures dictate an increase in evaporation which then leads to increases in precipitation. The in turn causes regional variations in rainfall. Overall they believe the global supply of freshwater will increase. Both droughts and floods may become more frequent in various regions at various times. Dramatic changes in snowfall and snow melt is expected. The World Bank report goes on to tell us that, "Higher temperatures will also affect water quality in ways that are not well understood."[28]

Climate change could likely mean a greater demand for farm irrigation and household use of lawn and garden water. They further state that, "There is now ample evidence that increased hydrologic variability, and change in climate, has and will continue to have a profound effect on the water sector through the hydrologic cycle." This will have broad effects which will influence "water availability, water demand, and water allocation at global, regional, basin, and local levels."[29]

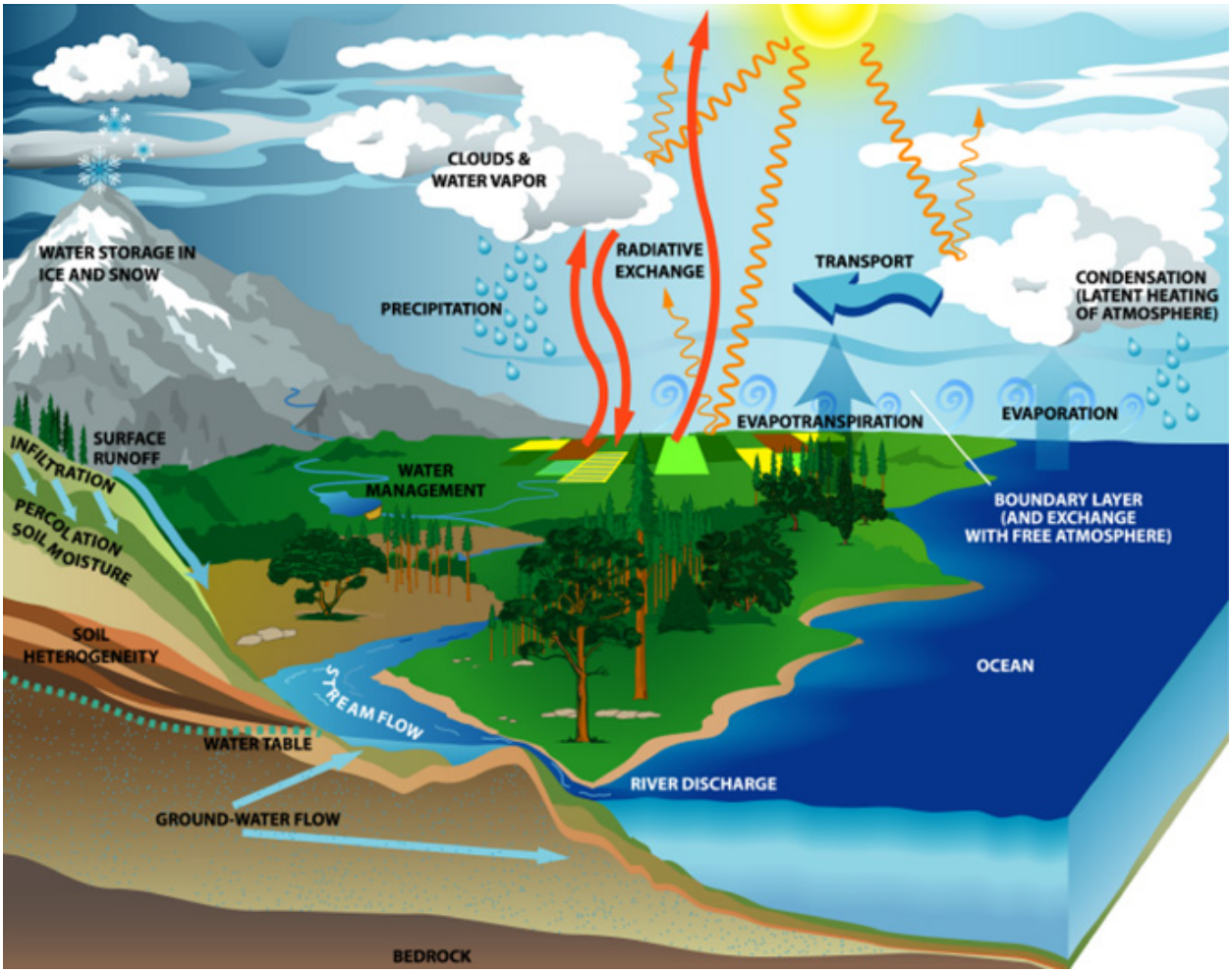


FIGURE 4. Water Cycle. *Source:* Blair County Conservation District, Pennsylvania.

Depletion of Aquifers

Countries are seeing growing competition for water as their populations grow. In fact many of the world's major aquifers are becoming depleted. This is due to the demand for human consumption as well as agricultural irrigation. According to *Groundwater and Urban Development*, "Millions of pumps of all sizes are extracting groundwater throughout the world. Irrigation in the dry areas such as northern China and India are supplied via groundwater. However it is being extracted at an unsustainable rate. Cities that have already experienced aquifer drops between 10 and 50 meters include Mexico City, Bangkok, Beijing, Madras and Shanghai."[30]

Pollution

Pollution is also affecting the amount of fresh water available to us. A simple definition of water pollution can be presented as "contamination of water which makes it unfit for use."[31] As far as fresh water in the United States is concerned, it has been observed that nearly 40% of rivers in the United States are polluted. They are not capable of sustaining healthy aquatic life. The water from these rivers should not be used for drinking or swimming. In addition 46% of lakes in the United States are unfit to adequately support aquatic life.[32]

Water pollution can be due to eutrophication which results in excessive growth of phytoplankton. The level of oxygen in this type of environment reduces to such an extent, that survival of fish and other animals comes under threat.[33] The issue of groundwater pollution is also quite prominent in the United States. Agriculture is considered to be an underlying factor in this. A study carried out in 49 states suggests that nitrate was the main contaminate of groundwater.[34] The discharge of agriculture waste also contributes to eutrophication.

According to the World Water Assessment Program (WWAP), 2 million tons of human waste is disposed in water bodies every single day.[35] As seen in Figure 5 below, the pollution in lakes across the United States from sewage factories accounted for 5% of the lake acres damaged. Agriculture is the major contributor and accounted for 18% of lake acres damaged.

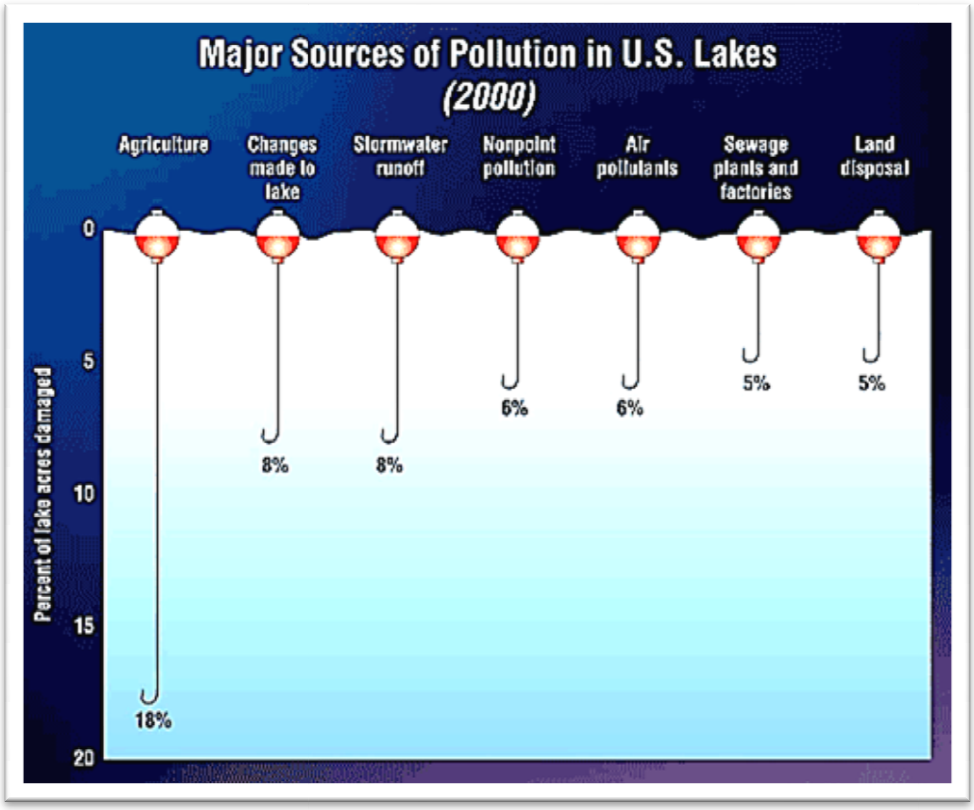


FIGURE 5. United States Environmental Protection Agency. 2000.

Urbanization

Urbanization is posing a threat to clean water. Developing countries have a major share in this as 70 percent of industrial waste is coming from these areas of the world.[36] The trend towards urbanization is accelerating and with this trend comes a greater demand for clean water.

Small private wells and septic tanks that work well in low-density communities are said to be non-feasible within the high-density urban areas. Furthermore it is believed that urbanization will require a significant investment in water infrastructure in order to deliver water to people and to process the large concentrations of waste water. This contaminated waste water will have to be treated or it could possibly pose a serious public health risk. The problem of sewage being released into bodies of water is often associated with developing countries where sanitation technology is deemed inadequate. However it is not only developing countries that are guilty of polluting our fresh water with untreated

sewage. According to water pollution facts and statistics from the Natural Resources Defense Council in 2011, as much as 850 billion gallons of untreated sewage is being released into 770 cities yearly.[37] Experts say that even if sewage is treated, problems can still arise. The treated sewage forms into a sludge, which will then be placed in landfills, spread out onto land, incinerated or dumped at sea.

SECTION 2: GREYWATER RECYCLING IN THE HOME

PART I: Greywater Defined

Sources of Greywater

Greywater is defined by Greywater Action as "water from your bathroom sinks, showers, tubs and washing machines. It is not water that has come into contact with feces, either from the toilet or from washing diapers."[38] Water from outside faucets should also be considered greywater. The water from home appliance usage makes up 50 to 80 percent of the water leaving residential homes through the sewage pipes.[39] All other water leaving the area is to be considered blackwater. Blackwater cannot be recycled due to current laws and the lack of technology. Unfortunately water from kitchen sinks, garbage disposals and dishwashers is considered blackwater in some states due to the high organic waste concentrations and the difficulties involved in reusing the water safely.[40] Greywater coming from residences can be recycled. Rainwater from one's property can also be recycled. These actions reduce the amount of water that a household consumes as well as how much is sent down the drain.

Rainwater Harvesting

Although this report is not focusing largely on rainwater harvesting it is a significant enough method towards water conservation, recycling, and consumption reduction that it deserves to be mentioned. Rainwater harvesting is a practice that is said to date back to pre-biblical times. More recently it has been used in India to exclusively recharge groundwater at rates exceeding natural recharge conditions.[41] This method is perhaps seen more in regions with arid climates where rainfall is scarce and every drop counts.

Rainwater harvesting at the residential level is basically the process of collecting storm-water runoff and putting it to beneficial use. The rainwater is intercepted from rooftops, patios, driveways, or any other impervious surface. Intercepted water is then retained and rerouted for other uses such as toilet flushing, plant watering, lawn and garden irrigation, pet and livestock needs, or evaporative cooler usage. [42]

The systems people use can range from very simple to costly and complex. Many homeowners simply collect water at the downspouts and then distribute it around the yard. In this way any type of barrel or container will do. In some parts of the world, houses have even been designed so that they provide an optimum rainwater catchment area.

Water quality issues with rainwater harvesting

According to an article published by Colorado State University, rain in urban areas may contain impurities absorbed from the atmosphere, including arsenic and mercury.[43] This is something to be cautious about. In Colorado rain is somewhat infrequent but the rainwater quality is generally very good. The infrequency of the rain there results in an accumulation of bird droppings, dust and other debris on rooftops between rain events. These can be in high concentrations when it does rain. Their best advice is to filter or screen out contaminants before they enter the storage container. Dirty containers could pose a health hazard or become a breeding ground for mosquitos and other pests.[44]

Uses for Greywater

Some uses for greywater are similar to those of rainwater harvesting. Homeowners who recycle their waste water are watering their shrubs and lawns. Many people who have opted for a more serious approach to water conservation are also flushing the toilets in their homes with the diverted greywater. The reclaimed water can also be used to recharge groundwater.

Advantages

The advantages to greywater recycling in the home are numerous. Homeowners are able to cut back on the amount of water that they use in the home, and in turn they are able to save money if they are paying for municipal water. The population on private wells and septic systems benefit as well, as the extra water reduces the strain on their systems.

On a larger scale many cities and towns have problems meeting the expense of expanding their wastewater treatment facilities as the demand for water grows. Municipalities may also be unable to extend sewage lines to urban areas which include fast-growing housing developments.[45] One way to solve this problem is to implement greywater recycling systems which conserve, protect and somewhat regulate the water usage at the point where it is used. It is possible that in-home greywater recycling can reduce or perhaps eliminate the need to expand public water treatment plants.

Plants and Soils

Household waste water recycling systems are a benefit to the plants and soil. Plants and topsoil thrive on wastewater. The greywater that is poured around them contains small bits of compost. This is said to encourage plant growth and also to apply topsoil treatments economically.[46]

Water Conservation

The American Water Works Association (AWWA) recommends some simple steps to help conserve water[47]. They are:

- Don't overwater your lawn. Keep it to 3 to 5 days per week in the summer and 10-14 days in the winter
- To prevent water loss from evaporation, don't water you lawn during the hottest part of the day or when it is windy.
- Only run the dishwasher and clothes washer when they are fully loaded.
- Defrost frozen food in the microwave or refrigerator instead of running water over it.
- When washing dishes by hand use two wash basins. One for washing and one for rinsing rather than letting the water run.
- Use a broom rather than a hose when cleaning sidewalks and driveways.
- If you have a swimming pool, use a cover. Homeowners can cut the loss of evaporation by 90 percent.
- Repair dripping faucets and leaky toilets. Dripping faucets can waste about 2,000 gallons of water per year. Leaky toilets can waste up to 200 gallons each day.

In addition to this advice homeowners can also install low flow toilets and showerheads, place aerators on faucets, use energy efficient front load washing machines, and landscape their yards with drought tolerant plants.

When a reservoir's water level gets low or a ground water table drops, water supplies, human health, and the environment are put at serious risk. Lower water levels can contribute to higher concentrations of natural and human pollutants.[48] Less water going down the drain will mean more water available for our lakes, rivers and streams. Using water more efficiently through greywater recycling may help us to maintain fresh water supplies at safe levels, which means protecting human health and the environment.

Monetary Benefits

Figure 6 shows the daily household water consumption and where it is used in the home. As one can see about 30% of water being used in the home is going through the toilet system. The other 55% is being used in the washing machine, shower and bath. Through greywater recycling the average consumer is said to experience a savings of approximately 30%.[49] Most of these savings will come from the toilets being flushed with the retrieved waste water and another large portion will come from the homeowner not having to turn on his sprinkler system to water the yard.

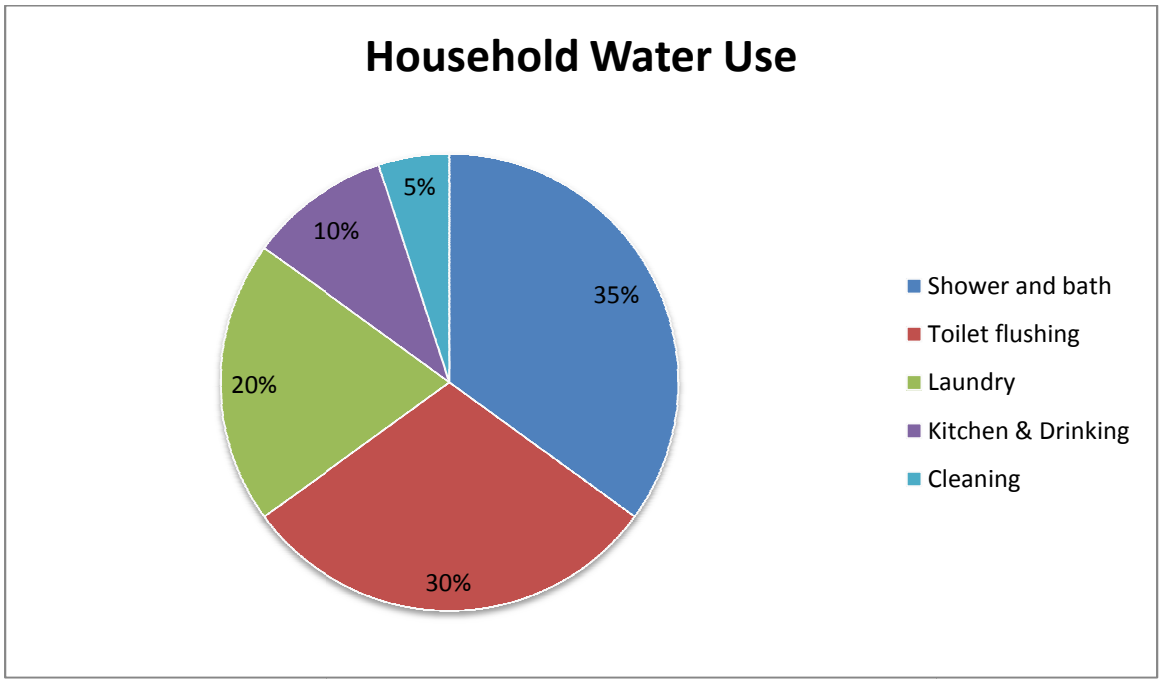


FIGURE 6. Household Water Use. *Source*: Property for Sale in Spain, Greywater Systems.

The exact cost savings is difficult to pinpoint as it will vary depending on the size of the home and the number of people living in the household. It can vary even more when one takes into account an individual's habits, lifestyle, schedule, and the cost of the utilities in different regions of the country. 'Grey is Green' has a website entitled "Greywater Recycling for the DIYer" which has a handy savings calculator to assist in figuring out this equation. The calculator, seen in Figure 7, asks the homeowner to enter information such as size of household, estimated number of flushes per day per person, the type of greywater recycling system they own, and the cost of different items that the system

requires for upkeep, such as filters and purification tablets. The savings seen below are based on a two person household, and show an annual savings of $360.00.

On a regional level greywater use has the potential to offer financial advantages to regional sewage treatment facilities. Their capital and operational expenditures may decrease because greywater use diminishes sewer flows, thereby lessening the need to expand their facilities.[50]

# People in Household:	**2**	**(must be 1 or greater)**				
# Toilet:	**1**	**2**	**3**	**4**	**5**	**6**
Flushes / day:	4	4	0	0	0	0
Minutes / flush:	3	3	0	0	0	0
Pump type:	AC	(*AC* or *DC*)			Average water savings (gal/month):	1200
Voltage:	115				Water cost ($/gal):	0.0055
Max current draw (A):	0.85				Annual water cost savings:	**$79.20**
Power supply standby current (mA):	0	(DC pump only)			Annual CO_2 savings (kg):	22.32
Energy rate ($/kW/hr.):	0.059					
Optional AAS run time (min/day):	15					
Annual consumption (kW/hr.):	**23.1911875**					
Annual energy cost:	**$1.37**				Annual Operating Cost:	**$15.78**
Annual CO_2 emissions (kg):	**10.4360344**					
Filter material length (in):	20				Annual Water Savings (gal):	*14400*
Filter material width (in):	30				Annual CO_2 Reduction (kg):	*11.884*
Bulk filter material cost ($/each):	7.00				Annual Dollar Savings:	*$63.42*
Cost per cut filter:	**$0.88**					
Filter change interval (weeks):	6					
Annual filter cost:	**$7.58**					
Bulk sterilizer tablet cost ($/pkg.):	21.00				Construction cost:	$350.00
# sterilizer tabs / package:	160				Payoff period (year):	*5.5*
# tabs added each period:	6					
Sterilizer addition period (weeks):	6					
Annual sterilizer cost:	**$6.83**					

FIGURE 7. Operating Cost and Savings Calculator. *Source*: Grey is Green.com (2012).

Septic systems

One aspect of greywater recycling is the burden it takes off of the septic systems. Waste water recycling systems divert much of the waste water onto the yard. Greywater from laundry washing machines are not recommended for septic systems. Laundry water accounts for about 20 percent of total septic system loads according to Oasis Designs in California. They state that "Gray water use greatly extends the useful life and capacity of septic systems."[51] They also educate consumers to be aware of the harsh soaps from the laundry water. This type of greywater is not recommended for septic systems as it kills beneficial bacteria inside the septic system. Any type of greywater recycling unit connected to the washing machine would therefore assist in keeping the soaps and chemicals out of the septic area through diversion.

Hazards

Greywater recycling does have a few negative issues surrounding its use. There are some who believe that greywater reuse is not a safe practice or product due to the fact that greywater contains bacteria and other pathogens. The main two issues would include health hazards from pollution and potential contamination, and the potential strain that might be placed upon municipal water systems.

Health

Let's Go Green is an organization that offers practical alternatives to sewer and septic systems. An article written by their experts states that, "Health risks are often cited by regulators as reasons for requiring high-tech expensive systems. There are no recorded transmitted illnesses in the United States. Greywater may contain infectious organisms. The consumer must keep this in mind when designing and using their system. A poorly designed system could easily become a pathway for infecting people."[52]

In order to avoid accidental contamination one should never water their edible fruits or vegetables with greywater. If untreated waste water is applied to the area and the food is eaten raw there can be potential health concerns. Also the consumer is advised to not recycle untreated greywater through sprinklers. The droplets can evaporate leaving harmful microorganisms in the air where they can potentially be inhaled.[53]

In 2007 California reported all of their greywater related diseases and whether they were reportable or related to greywater usage. One can see that there were zero cases that could be attributed to greywater. The data from California regarding disease occurrences linked to greywater is found in the bottom portion of Table 2.

TABLE 2. California Policy Data and Calculations.

Datum	What	Date	Source	URL, comment
Greywater system exposure in California				
36,553,215	Population of caliornia	2007	US census bureau	http://quickfacts.census.gov/qfd/states/06000.html
13.9%	Households with greywater systems	1999	Soap and Detergent Manufacturer's Association Graywater	p. 14 http://www.sdascience.org/docs/Graywater_Habits_&
5,080,897	Greywater users	2009	Calculation; population * percent greywater users	extrapolation from 1999
2.87	People per household	2000	US census bureau	http://quickfacts.census.gov/qfd/states/06000.html
1,770,347	Greywater systems	2009	Calculation; greywater users / people per household	(this assumes the proportion of greywater use has not chan
System user years-CA		*Note: This is a back of the envelope-type calculation; the point is still valid if it is off by a factor of two or four*		
5,080,897	Greywater users	2009	from above	
10.0%	Households with greywater systems	1950	Estimate; in general, older infrastructure has more greywater use, approaching 100% with rural 70+ year old buildings	
10,586,223	Population of caliornia	1950	US Census Bureau	www.census.gov/dmd/www/resapport/states/california.pdf
1,058,622	Greywater users	1950	Calculation; population * percent greywater users	
3,069,760	Average number of greywater users	1949-2009	average of 2009 and 1950 greywater users	
60	Years from 1949-2009		calculation	
184,185,576	System-user-years of greywater exposure, not counting neighbo		caculation; average greywater users * years	
Greywater system exposure in United States				
303,824,640	Population of US	2008	CIA estimate	https://www.cia.gov/library/publications/the-world-factbook/p
7.0%	Households with greywater systems	1999	Soap and Detergent Manufacturer's Association Graywater	http://www.sdascience.org/index.php?option=com_content&
21,267,725	Greywater users	2009	Calculation; population * percent greywater users	extrapolation from 1999
2.59	People per household	2000	US census bureau	http://quickfacts.census.gov/qfd/states/06000.html
8,211,477	Greywater systems	2009	Calculation; greywater users / people per household	extrapolation from 1999
System user years-US		*Note: This is a back of the envelope-type calculation; the point is still valid if it is off by a factor of two or four*		
21,267,725	Greywater users	2009	from above	
10.0%	Households with greywater systems	1950	Estimate; in general, older infrastructure has more greywater use, approaching 100% with rural 70+ year old buildings	
152,271,417	Population of US	1950	NPG historical data	http://www.npg.org/facts/us_historical_pops.htm
15,227,142	Historic greywater users	1950	Calculation; population * percent greywater users	
18,247,433	Average number of greywater users	1949-2009	average of 2009 and 1950 greywater users	
60	Years from 1949-2009		calculation	
1,094,845,995	System-user-years of greywater exposure, not counting neighbo		caculation; average greywater users * years	
Reports of graywater-transmitted illness in US				
0	Reports of greywater-transmitted illness		18 years of greywater policy discussion, Letter from CDC	
400	People struck by lightning in the US, per year	2008	NOAA lightening safety	http://www.lightningsafety.noaa.gov/medical.htm
344	People drowned in bathtubs	2005	National saftey council	http://www.nsc.org/research/odds.aspx
Greywater system permit compliance rate in California				
1,770,347	Greywater systems	2009	from above, extrapolation from 1999	(this assumes the proportion of greywater use has not chan
200	Permitted greywater systems	1992-2009	ReWater Systems, 70±, Bill Wilson + Kevin 20±, Ted Adams, 5± Art Ludwig, 2±…rest are a guess. I'd say lower bound is	
8,852	Ratio of unpermitted to permitted systems		calculation	
0.011%	Percent of permitted systems		calculation	

Reportable GW Diseases, Potential & Reported	Total Cases		
Disease	in 2007	Est. 60 Years Cumulative Cases	Cases Linked to Graywater
Cholera	7	288	0
Cryptosporidiosis	11,170	502,650	0
E. coli, Shiga toxin-producing (STEC)	4,847	218,115	0
Giardiasis	19,417	873,765	0
Hepatitis A	2,979	134,055	0
Legionellosis	2,716	122,220	0
Salmonellosis	47,995	2,159,775	0
Shigellosis	19,758	889,110	0
Vibriosis (non-cholera Vibrio species infections) §	447	20,115	0
Totals	**123,713**	**4,920,093**	**0**

Source: Ludwig (2009)

Negative Effects on Municipal Water Systems

There is a concern among some experts that greywater recycling could actually pose a threat to the health of our municipal water treatment facilities. Experts from Colorado State University believe that diminished flows may have a downside because greywater can result in insufficient sewer flows to carry the waste to the sewer plant. Another concern they have is that with the increased use of greywater, the less effluent water will be available for treatment. This would result in less reclaimed water for municipal uses for downstream appropriators.54

Part II: Home Greywater Recycling Systems

Methods and Usage

There are two general uses for greywater. One is using the recycled water for landscape and outdoor purposes, and the other is utilizing the reclaimed water for indoor toilet flushing. Some greywater systems take water used in the laundry and then discharge it directly into the yard. This is termed landscape direct. In other systems water can go through an initial filtration process before being expelled. There are designs and methods in varying degrees of complexity. The methods for recycling greywater can range from a simple collection bucket kept under the bathroom sink, to a complex commercially designed plumbing system branched throughout the entire home. There are many companies in which one can order commercial greywater recycling units to be shipped to their home, which are then either self-installed or put in with the help of a qualified professional. There are also workshops, instruction booklets, and websites online for the homeowner's who desire the "Do-it-Yourself" approach and wish to install a unit on their own.

Home Greywater Recycling Systems

The simple systems range from $0 to $200. Most of these would be considered "Do-it-Yourself" systems where the homeowner would purchase the equipment and install it himself. Many manually operated systems will require some slope unless a pump is purchased at an additional cost. Gravity is an important factor for flow rate in manually operated systems.[55]

The more complex systems treat greywater prior to disposal to reduce groundwater contamination or surface ponding problems. Many of the systems are designed to remove pollutants and bacteria from greywater. These more advanced systems will include settling tanks, sand filters, electronic controllers and valves. Improvement in technologies

and system's innovations are regularly occurring.[56] The cost of some of these commercially designed and professionally installed systems could be as much as $30,000 for a large custom home, according to Oasis Design.[57] This is found more frequently in areas where the permit process and regulations are strict and enforced. Installing and implementing these systems on one's own is a much less expensive alternative. Treating the water to the point of sterilization in order to reuse it inside the home, as opposed to the yard, is another reason for the higher cost. There are greywater systems that are designed for landscape only. These systems can cost from a few hundred to a few thousand dollars.

Do-It-Yourself Systems

Do-It-Yourself systems range in level of complexity and cost. One must decide how much time and effort they wish to put into the process of recycling greywater. The options are many. There are very simple greywater recycling systems which divert the recycled water directly onto the landscaping and they are termed *landscape direct*.[58] Some of these methods would not be considered legal in certain states where there are greywater recycling regulations. These methods are an illustration of how greywater recycling began. Do-It-Yourself system methods are still practiced in those parts of the world where homeowners have the need to reclaim water but cannot afford the expense. In the majority of these simple systems, there is generally no standardized filtering or sterilization of the water.

The advantages of simple Do-It-Yourself greywater recycling systems:

- No filtration necessary
- No pumping necessary
- No surge tank necessary
- Little pipe is needed
- Little or no required maintenance
- Low economic and ecological cost
- It can be built by anyone
- Low failure rate (that is, they are little worse in year 100 than year one)
- They last forever[59]

According to Art Ludwig, author of a book series entitled "Create an Oasis with Greywater," some of the disadvantages of these simple systems are:

- Low reuse efficiency

- Poor sanitation
- Soil overload
- Poor aesthetics
- High flow to one area of the yard

Bucketing

Bucketing refers to the placing of a bucket or other receptacle under the sink in the bathroom for collecting greywater. The water is then manually carried outside, and poured directly around the trees and shrubs that need watering, or it is placed into the toilet tank for flushing. The Greywater Guerrillas suggest the homeowner disconnect the bathroom sink drain from the sewer pipe with a wrench, leaving the P-trap in place[60]. This method is of zero cost to the homeowner. The Ecology Center in Berkeley, California also mentions that people can bucket out their bathwater or even take a bucket into the shower and use that water to flush toilets and water plants.[61]

Hose out the window

Another landscape direct system that puts the greywater directly out into the yard is the "hose out the window" method. It has been around for years and is as simple as running a hose through the bathroom window in order to empty one's tub. The homeowner would need to move the draining hose often. The water could oversaturate an area if many baths were being taken. In Paul James' book "Graywater Gardening---From Buckets to Irrigation Systems, a detailed guide to help you determine what is best for your garden!" he says that people need to distribute water evenly across the garden. He warns that plants can quickly die from overwatering.[62]

Laundry to landscape

The laundry to landscape method sends the water from the washing machine directly out into the yard. As seen in Figure 8 there are mulch basins around the trees which are receiving the greywater. Mulch basins are a simple and natural method of filtration. According to Art Ludwig who authored, "Create an Oasis with Greywater" he says that greywater must pass slowly through healthy topsoil in order for natural purification to occur.[63] Soil alkalinity can be an issue with this method in regards to landscape health. This is discussed in more detail in the section *Preferred Practices in the Garden*.

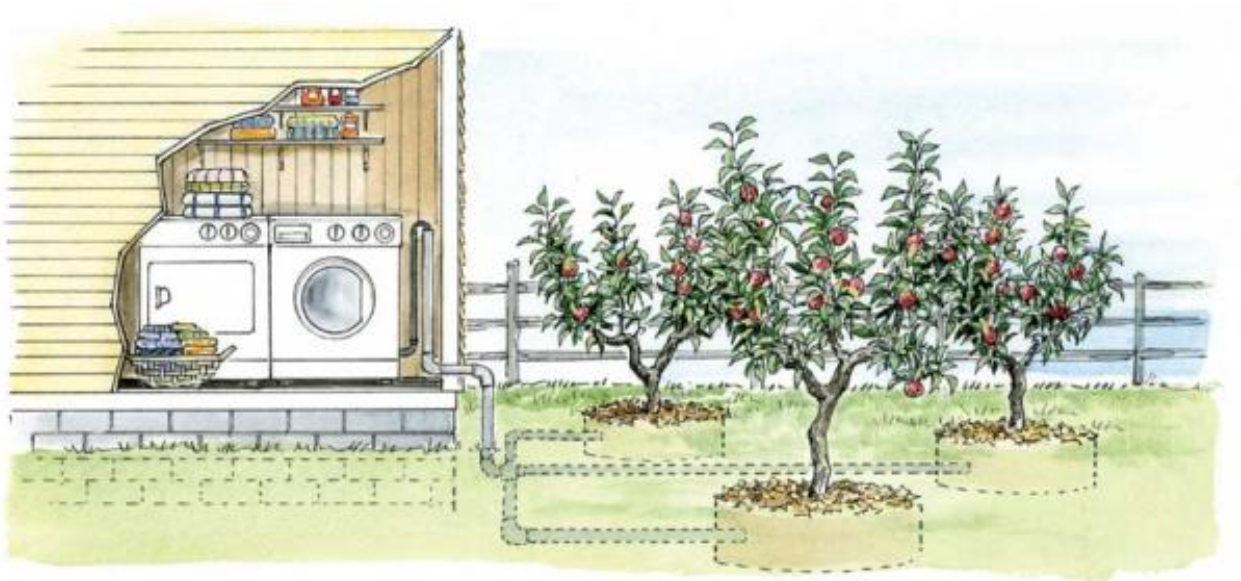


FIGURE 8. Illustration of the Laundry to Landscape method. *Source*: Mother Earth News. Illustration by Laura Allen and Cleo Woelfle-Erskine. August/September 2011.

Laundry drum

The laundry drum system is similar to the system with the addition of a surge tank to accommodate large outflows of water into the system (Figure 9). This is not an actual storage tank. Instead it is there to allow the irrigation time to catch up with water flowing into the system. The washing machine discharge flows into a 55-gallon plastic drum which is placed just outside the home. From there the greywater is distributed to the landscape via a hose. The hose is then moved periodically to different locations throughout the yard. This system can be installed with little or no modification to the house and yard.[64] This is slightly better than the landscape direct method as the water can sit in the barrel until it cools off. Often the wash water coming out of the machines is hot.

This method may cost anywhere from $20 to $100 depending on the quality of drum the homeowner chooses. The same overwatering and pH issues and precautions should be noted as seen in the "Laundry to Landscape" system.

FIGURE 9. Drum Used for Greywater Recycling. Photo courtesy of Instructables.com (2012).

Branched drain

A branched drain system solves the issue that simple systems have when there is too much water flowing to one area. By splitting the flow the homeowner can distribute water more evenly onto the chosen areas of the yard, as illustrated in Figure 10. Again mulch basins are utilized. There is one major requirement that needs to be met in order to consider this method. The greywater irrigation zone must be downhill relative to the greywater source (sink, laundry, and shower) inside the home. This complex system has no pump and relies on gravity for water flow.

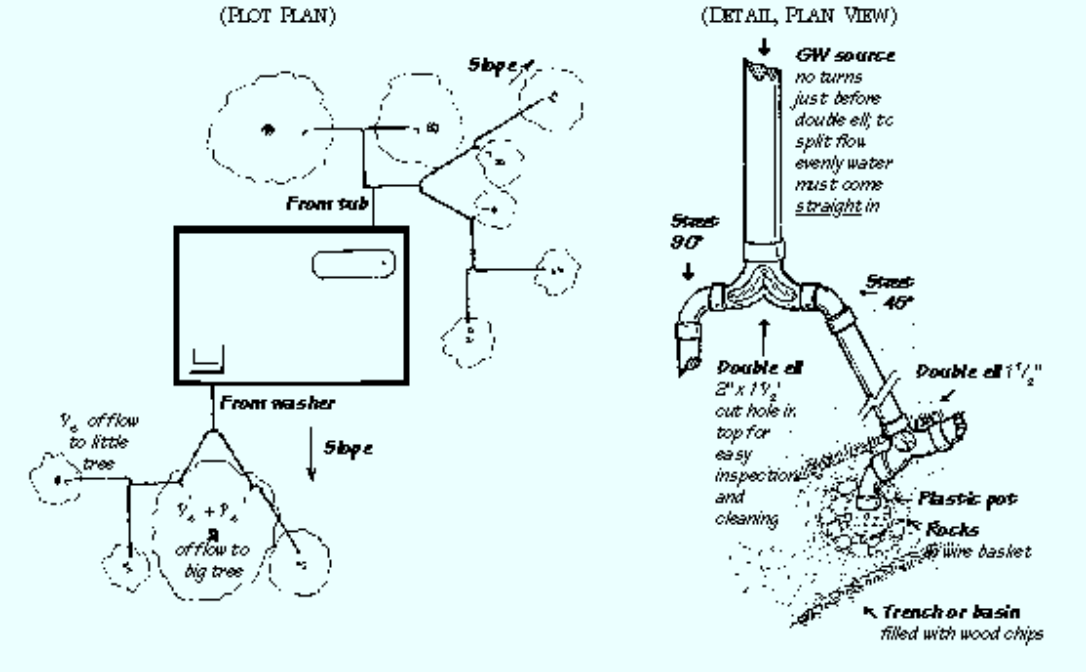


FIGURE 10. Branched Drain Plot Plan and Double Ell Detail. *Source*: Oasis Design Inc. (2009).

The plumbing involved is minimal. Many small networks can be made with a $100.00 investment in materials. Larger systems can cost upwards of $400.00, according to the staff at TheGreywaterGuide.com.[65] In order to distribute the greywater to more than one locale, a double ell is recommended. This is a special type of T fitting. More than one can be used to further split the flow. The experts in the field of greywater use and system design tell us that the flow could be broken into as many 16 directions. Eight is the most practical number for the average household.[66] For homeowners that live in a climate where there is a rainy season, Cleanwater Components suggest using a 3-way diverter valve instead of the split valve. This method will allow the homeowner to send greywater to the sewer if desired when the yard is already overburdened with moisture[67].

This method is only suitable for the household that generates less than 300 gallons a day of greywater (15-35 gallons/day/person.)[68] Larger flows would require a more complex system with pumps and possibly holding tanks. Figure 11 also illustrates a landscape model for the branched drain design as well as the basic plumbing involved. Here we see 11 shrubs and trees benefitting from used bath and laundry water. There is a definite slope that directs away from the home to show that gravity is the driving force for the system.

Subsoil greywater irrigation

Greywater filtering and irrigation systems can be purchased through a number of suppliers and companies. The homeowner can choose to hire a plumber or landscaper for assistance in this method, depending on his individual level of expertise. Most of the companies will openly state if a professional installer is recommended for a particular system. When one gets into large custom homes, and large landscape areas, the costs can rise substantially due to the labor involved. Below (Figure 11) is a photo of a subsoil greywater irrigation system being installed with drip lines.[69] A household of 4 people will generate over 100 gallons of greywater on any given day.[70] IrriGRAY is a company specializing in drip line technology for greywater irrigation systems. They estimate that a household generating this much greywater can irrigate between 2,000 and 3,000 square feet of garden area. Table 3 shows the breakdown for reference purposes.

FIGURE 11. Subsoil Irrigation System Installation. *Source:* Advanced Greywater Recycle Systems (2012).

An irrigation station similar to a sprinkler station system needs to be installed for these types of projects. The price for a station by a company out of California is $4583.00 as seen in Table 4[71]. This does not include the cost of the drip line or the specialized junction box that will need to be installed if the yard does not already have one. The estimate for that box is $2995.00, bringing the total to $7578.00. These prices are for necessary operational parts and do not include the cost of an electrician or landscaper if one is needed. This is the least expensive model they offer. It operates 21 stations. It comes with a sand filter and is approved by the state of California.

TABLE 3. Estimated Area of Greywater Coverage Based on Household Size.

# of Persons	**Garden Area (square feet)**
1	500 - 750
2	1000 – 1500
3	1500 – 2250
4	2000 – 3000
5	2500 – 3750
6	3000 – 4500

Source: Just Water Savers USA (2009-2012).

TABLE 4. Greywater Irrigation System Cost Analysis.

Greywater Irrigation System	
Item	**Price**
Polyethylene Surge Tank 70 gallon w/ gasket material	$953.00
Structural Poly Bolt-on HD Lid with 6 SS Screws	$215.00
Bulkhead Adapters, 3 @ 2", 1 @ 1 1/2", 2 @ 1/2"	$103.00
2" Discharge Pipe w/ male adapter, & sweep	$35.00
3-Way 2" Tee Valve w/ 24 VAC actuator	$455.00
19" Filter Vessel wrapped fiberglass	$648.00
Filter Vessel Pipe Adapter	$55.00
1" Solenoid Valve, nylon, for backwash	$85.00
1.5" PVC Swing Check Valve	$34.00
120 VAC ½ HP high-head effluent pump	$1,120.00
Float Switch w/ 20' Cable	$98.00
2" Backflow Valve w/ viewing port	$72.00
1" Solenoid Valve, nylon, for irrigation supplement	$85.00
Pressure Regulator for 1" supplement valve	$83.00
1" In-line over-sized Y Filter	$78.00
1" Reduced Pressure Principle Device	$456.00
RWJB1, NEMA 3 Junction Box w/HD contactor (optional)	($2,995.00)
Owner's Operation & Design Manual	included
"Caution, Non-potable Water – Do Not Drink" stickers 25	$5.00
14" Plastic Ties for securing pump & float wires, 3	$3.00
Retail Value	**$4,583.00**

Source: ReWater Systems (2011).

Filtration

There are many choices and methods to filtering. Again there are simple, inexpensive ways to filter greywater, and there are expensive manufactured devices a homeowner can purchase. There are even ways to implement several of these methods into the home. For instance one could use a filtered system for his laundry to landscape method, and then use the bucketing method in another bathroom in the home. The main filtering methods for the Do-It-Yourself homeowner are mulch basins, sand filtration, settling tanks, and commercially purchased filters.

Mulch basins

Mulch basins are simple to construct. They can be maintained at very little cost. For best results the homeowner would need to replenish the wood chip mulch every year or so as the older chips turn into compost. To construct a basin one can size the area based on soil type and amount of greywater produced. For clay soil one square foot of soil per one gallon of greywater is required per day. If an estimated 10 gallons per day were discharged that would mean 10 square feet of mulched area to accommodate the flow. Sandy or loam soils need less area.[72]

Mulch basins are known to be good for the soil. "Greywater Designs" constructed a greywater system utilizing the mulch method and stated the following about one of their projects located in the Willamette Valley of Oregon, "The composting mulch surrounding the infiltration chambers teems with worms, arthropods, fungi, molds, roots, etc. As compared with a conventional septic system and leach field, the level of water treatment in this system is almost certainly higher due to greater oxygenation through the wood chip mulch and to high levels of biological activity within the mulch." They further go on to say that, "Scientific research has shown that tree roots are effective in absorbing significant quantities of nitrogen, one of the two pollutants health authorities are most concerned with in residential wastewater systems.[73]" A photo of the healthy composting mulch is seen in Figure 12.

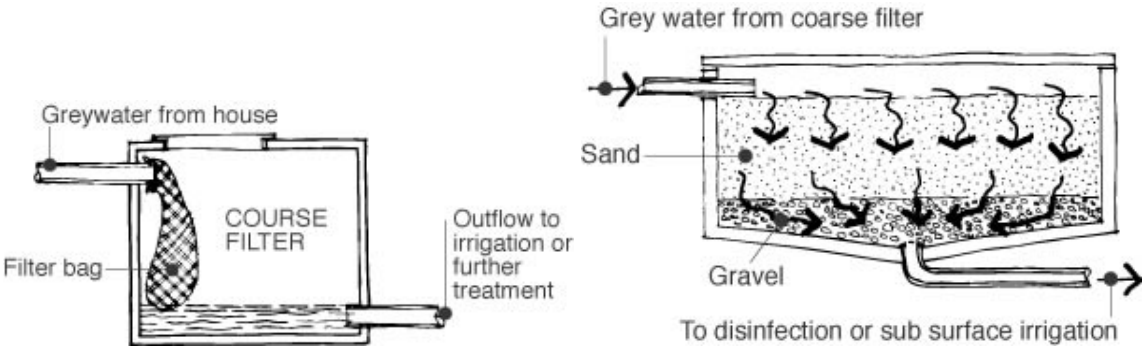
FIGURE 12. Healthy Mulch Basin Soil. *Source:* Omick (2012).

Sand filters

Sand filters are a natural method by which to filter out greywater prior to reuse. This Do-It-Yourself method of filtration is a 2-step process. Step one requires a filter bag and a tank. The greywater comes from the home's bathroom sink and/or shower and tub areas and is filtered through a mesh filter bag. This removes any large particles such as lint or hair immediately. This basic filtration method is shown in Figure 13 as step one in a 2-step process.

The second step is a greywater sand filter. The water treated in the first step with the course filter is then sent into another tank filled with sand. This apparatus is made up of a thin layer of gravel topped off with a much thicker layer of sand. The container must be waterproof and could be a bin or barrel. The coarsely filtered water passes through the sand being finely filtered as it moves towards the bottom. The deeper the layer of sand, the better the filtration tends to be.

A company in the United Kingdom sells the parts for this type of system. They explain that in a system lightly used, the sand needs to be washed regularly to remove any accumulated particles between the grains of sand. However in a system that is in use continually, a slow and constant flow of water through the filter leads to biological activity. The top layer of sand in the filter traps microorganisms. These bacteria then digest disease-causing pathogens when they too get trapped in the sand. In time a bio-film will build on top of the sand through which few pathogens will be allowed to pass. Without the constant flow of greywater, biological activity can cease and the layer will become stagnant.



Step 1 - Course Filter Step 2 – Sand Filter

FIGURE 13. Steps of Greywater Sand Filtration Process. *Source:* REUK.co.uk (2012).

Settling tanks

A greywater recycling settling tank is another method of natural filtration that does not use chemicals. The tank shown in Figure 14 can be buried in the ground. The greywater comes into the tank much like a septic system and the solid debris settles to the bottom. Any grease or oil rises to the top. As household wastewater flows into the tank the clarified greywater irrigation water flows out.[74] The water can then be disinfected for household use or go straight out to subsurface irrigation. It is also not recommended to use greywater that has been in the filtration system for more than 24 hours or bacteria will build up affecting the water that is being reused.[75]

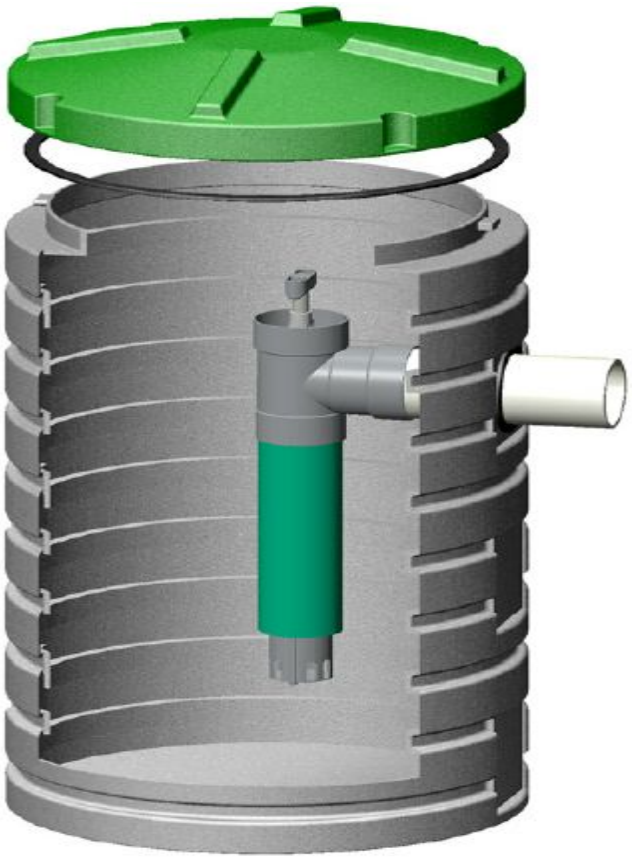


FIGURE 14. Commercial Greywater Settling Tank. *Source*: The Natural Home (2012).

Commercial filters

A commercial filter system would be considered anything a homeowner would have to special order. The multi-stage filtration box seen in Figure 15 is designed for easy installation and cleaning. Many other greywater systems use chemicals to treat the water. The filter and pump have a cost of just over $700.00. The filter is reputed to filter tens of thousands of gallons of greywater before it ever has to be cleaned. When maintenance is required the pads pull out easily for washing.76 Since no chemicals are used this system can be used for drip irrigation. There are six chambers that the water must be processed through to collect all lint, hair and impurities. There is a pump that is signaled when the tank is full, or it has been 24 hours. The water is then let out into the yard. In the event there is overflow, or when the yard becomes saturated, there is a diverter valve that is activated and the excess water is then sent from the overflow basket out to the sewer. Maintenance on this system is low. All that is required is washing the filters every four to six months. This filter can be used with or without a pump. If the homeowner chooses it

can also be turned into a gravity controlled system much like the branched drain. The company that has patented this filter design states that if a family of four were to use this system, they would save 40,000 gallons of water annually.[77]

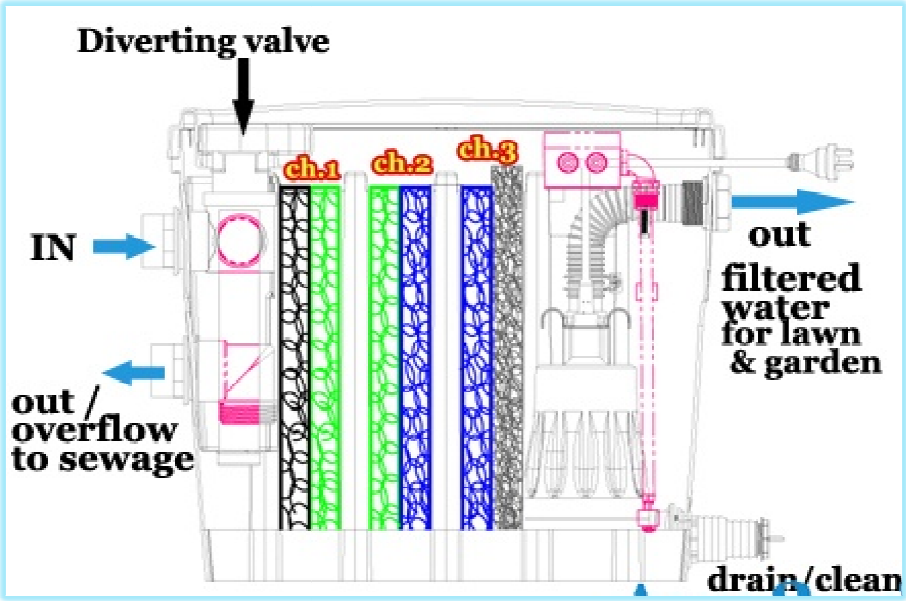


FIGURE 15. Depiction of a Commercial Greywater Filter System. *Source*: Aqua2use (2010).

Purification

It is necessary to sterilize water if one wishes to keep algae, viruses, bacteria and other organic contaminants from forming inside the storage tanks. Chloronization is used most commonly. Other systems utilize ultraviolet light that exposes the water to a specific wavelength. This in turn destroys the DNA of organisms present. The advantages to UV light sterilization is that it uses no chemicals to kill the pathogens. It is less expensive than chlorinization and there is minimal maintenance.[78] The greatest disadvantage, according to Water Harvesting Solutions, is that the UV light can only kill the pathogens that are exposed directly to the tubes. There is no residual killing off of harmful bacteria as seen with the chlorine. This can lead to fouling of filters and bacterial growth in other areas of the system.[79]

System Comparisons

The methods and systems described all have advantages and disadvantages to them. Table 4 puts six methods into a template for comparison. The homeowner may use this template to decide what method is most suitable for him or her. The main points to be compared between these systems are: ease of installation, initial costs involved, filtration, sterilization options, ease of maintenance, ease of greywater distribution, adaptations to freezing temperatures, and legality.

The systems which are easiest to install also seem to be of least cost, but they are hardly legal in areas where greywater recycling is regulated. These more involved projects that involve filters are also designed to pass the permit process in regions with strict rules on greywater usage.

The least expensive methods also are the most difficult when it comes to distribution. This is due to the fact that they either involve more physical labor, as in bucketing, or more time. According to Greywater Action, a collaborative group based around sustainable waterculture, the costs listed below in Table 5 for these systems, reflect the price if one self-installs[80]. The costs go up considerably if outside help is hired.

The more expensive Do-It-Yourself methods have greater ease of distribution. They may cost more up front but they are the methods that will most likely be less work in the long run. Although the branched drain is higher in maintenance than most other methods, only monthly inspection is needed of the double ells to ensure they are clean from debris. The mulch basins for all systems must be checked regularly as well.

TABLE 5. Greywater Recycling Systems Comparison Chart

Method	Ease of Install	Initial Costs	Legal in All States	Filtration	Sterilization	Maintenance	Adaptations to Freezing	Ease of Distribution
Bucketing	**Easy**	**$0**	**No**	**No**	**No**	**Easy**	**Yes**	**Hard**
Hose out the Window	**Easy**	**$0**	**No**	**No**	**No**	**Easy**	**Yes**	**Hard**
Laundry to Landscape	**Easy**	**$0**	**No**	**Optional**	**Optional**	**Medium**	**Maybe**	**Medium**
Laundry Drum	**Medium**	**$20-$100**	**Maybe**	**Optional**	**Optional**	**Medium**	**Maybe**	**Medium**
Branched Drain	**Hard**	**$200-$400**	**Maybe**	**Optional**	**Optional**	**Hard**	**No**	**Easy**
Subsurface Irrigation w/Filters	**Hard**	**$5k-$10k+**	**Yes w/ permit**	**Yes**	**Optional**	**Hard**	**No**	**Easy**

Before You Start

Before embarking on installing a greywater system there are several things one must consider. The homeowner should look at the various methods and see just how much time, energy and money they would like to put into a system. There are safety, drainage, soil, and garden issues that should be considered. There are also local rules and regulations surrounding the use of greywater in some areas. Even a small amount of research can often save people time and trouble. Art Ludwig of Oasis Design believes these steps are key when planning a new system:

- Design the mulch basins and outlets
- Make fine adjustments to the design during construction
- Define system goals and design assumptions
- Assess greywater sources
- Assess irrigation need
- Connect greywater sources with irrigation need on a site plan
- Decide whether or not to combine all flows before splitting them
- Design the plumbing details[81]

Preferred Practices in the Garden

Any products used in the shower or laundry will end up in the irrigation water. Care should be used when selecting cleaning products. Although most soaps and shampoos are relatively safe for plants, laundry soap and cleaning agents do vary.[82] Salt, alkalinity and overwatering can be detrimental to plants. The vast majority of plants thrive on greywater, according to Paul James, author of "Greywater Gardening." They do not need pure water. Fruit trees and vegetable plants actually perform better with greywater.[83]

Salt

Salt is a common problem seen in homes with water softeners which use large amounts of salt. Softened water should not be used in the garden. Non-concentrated soap powders also contain high levels of sodium used as fillers. It is preferable to use either liquid detergents or concentrated powders that are low in salt.

Alkalinity

Most washing machines produce a highly alkaline greywater with a pH of approximately 10.5 during the first wash cycle.[84] If this water is repeatedly distributed to one area it will kill plants. The preferred practice here would be to move the hose from one area to another in order to reduce this risk and evenly irrigate the yard. Furthermore when soil is high in pH, micronutrients are bound to the soil, and therefore unavailable to plants. Iron chlorosis can develop and the result is leaf yellowing.

Plants

Greywater is said to be hard on acid loving plants as the water that is placed on them is often very alkaline. The jury is still out on this as some gardeners have seen good results with azaleas and other plants in this category. This problem could be avoided if the washing machine water were directed onto plants other than this type. Plants native to dry areas do not like a lot of water period and should not be overly irrigated in the dry season. There are also cultivated plants that do not like soggy conditions. It is best to avoid irrigating plants that do not like a lot of water, and to design a system that will not create soggy conditions for plants that cannot tolerate it.[85]

Fruits and vegetables

Fruit trees and vegetables grow well with greywater. However there is a risk that greywater can contain bacteria. It is very important not to allow the greywater to come into contact with a fruit or vegetables for this reason. A person could become ill if untreated greywater were held for over 24 hours and bacteria were allowed to grow, or if a homeowner were using greywater from the kitchen area and bucketing onto edible plants. These practices are not recommended. The preferred practice would be to distribute the water into a soil or mulch basin, or carefully around the base of the plant. In the event a homeowner is unsure if there has been contact, it is recommended that all vegetables and fruit be washed thoroughly and peeled before eating.[86]

Some vegetables are not recommended for irrigating with greywater as they are root vegetables. Because the skin is rough the radish is not a good choice. This makes it difficult to clean. Due to the green onion's layered structure, it is also not recommended as bacteria could be trapped within those layers. Lettuce can be irrigated by subsoil but if it is watered from above the leaves could be contaminated. Carrots, onions, potatoes, or other vegetables that are to be cooked are fine. The heat in the cooking process will kill any bacteria that are present.[87]

Irrigation pipe

Drip irrigation pipes require that the water coming through them be filtered and free of particulate matter.[88] If there are small particles in the water, the drip emitters will become clogged and the system will fail. Unfiltered greywater contains hair, lint, and other thick matter. For all the time and money spent on a complex drip irrigation system, it may be wise to invest in a filter. Oasis Designs recommends using 1 ½ inch to 2 inch pipes for all greywater irrigation.[89]

Slope

In terms of the branched drain, or any system without a pump that is relying on gravity for flow, a slope of 2% or ¼ inch per foot is required. The pipes must be sloped to exact tolerances in order to work. If the lot the house sits on slopes less than this, the deeper the lines will need to be, and the further from the home as well. The steeper the lot and the higher the plumbing is above grade, the easier it is to lay the pipe.[90]

Greywater Safety

Greywater that has not been sterilized should not be stored. Although some methods of recycling greywater involve the use of a drum or barrel, this water should not be held for more than 24 hours. Greywater should be used immediately. Greywater has nutrients and organic matter that when left sitting can begin to decompose and give off a malodorous smell. These bacteria can be harmful to humans and pets. Since untreated greywater is not fit for human contact, it is not recommended for use in waterfalls, creeks, ponds, or any other type of water feature.91 Greywater is also not recommended to lawns. The only method proven safe for watering of lawns is an underground drip system supplied by a backwashing sand filter.92 This is due in part to the way people use lawns. Children and pets play on lawn areas and people walk on them. This could contribute to contamination. To date there have been no reported cases of illness in relation to greywater recycling.[93]

Mosquitoes can be a problem in some areas and it is wise to not allow greywater to pool anywhere in the yard. This could become a breeding ground and therefore a public health hazard. Make sure greywater soaks into the ground and does not create a run off issue onto neighboring areas where anyone could come in contact with it.

Use gloves during maintenance and when cleaning out any irrigation pipes used in a home greywater recycling system.

Regulations Concerning the Use of Greywater

Governmental regulations concerning domestic greywater use for landscape irrigation is still developing. This issue is gaining wider support as the risks and benefits are weighed. The pure legal description of greywater is still considered in some jurisdictions as 'sewage.' In several states that have adopted the *International Plumbing Code,* it can be used for subsurface irrigation and toilet flushing. In states where greywater is still considered sewage, it is bound by regulatory procedures to ensure properly designed septic and disposal systems are installed. In these places that has meant domestic greywater landscape irrigation was simply not permitted.[94]

In a policy enacted by the Department of Environmental Quality in March of 2010, California, New Mexico, Utah, Wyoming, and a few other states are now allowed to use surface and subsurface irrigation. This includes other non specific uses as well. In a 2009 Legislative Session the state of Montana passed a bill expanding the use of greywater in multi-family and commercial buildings. Montana is the only state that has approved the usage of greywater coming from the dishwasher. This particular appliance has never been included in greywater codes before, as the greywater from kitchens and kitchen sinks is normally excluded.[95]

Greywater policies truly differ from state to state. One of the prime examples for greywater policy is currently found in the state of Arizona. This state has greywater guidelines for citizens to follow. They educate residents on how to build safe, efficient and effective greywater systems. If the homeowner follows the guidelines, their system falls under a general permit category deeming it legal. The residents following this procedure would therefore not have to apply or pay for any further special permits.[96]

Wherever a homeowner lives in the United States, it is best to check for local regulations and codes pertaining to greywater recycling before beginning the process.

Informational Resources for the Beginner

Books, organizations and websites exist to help homeowners who wish to begin greywater recycling. Depending on the scope of one's greywater aspirations, many more topics may need to be considered. There are many more factors to consider involving the local climate, soils, landscaping, plumbing, materials, permits, and more. Informational resources that can further aid in directing and educating the homeowner during this process are listed below.

Websites

www.graywatergardening.com
www.greywater.com
www.thenaturalhome.com
www.oasisdesign.net

Books

Greywater Gardening-From Buckets to Irrigation Systems. A detailed guide to help you determine what is best for Your Garden! by Paul James. (Just Water Savers USA Inc., 2010).

The New Create an Oasis with Greywater: Choosing, Building and Using Greywater Systems – Includes Branched Drains. By Art Ludwig. (Oasis Design, 2006).

Organizations

www.ecoact.org
www.greywateraction.org
www.greywateralliance.org

Part III: A Survey of Interest in Greywater Recycling Systems

A random survey of 20 people was conducted at a local shopping mall in Pocatello, Idaho. The 20 people surveyed were given an informational brochure outlining some basic facts about greywater and then asked to answer a series of 14 questions. The survey was implemented in order to find out people's level of interest in greywater recycling in the southeastern Idaho area. The main purpose of the survey was to discover whether:

1. Residents in the area were aware of the concept of greywater recycling
2. People would be likely to share information on greywater recycling
3. Residents found the cost of installing a system to be reasonable
4. People would be likely to install a system if they could save 30% on their water bill, and if:
    a. People on well water and/or septic systems would be likely to install a greywater recycling system
    b. There is a correlation between high water bills and the likelihood of installing a greywater recycling system
    c. There is a correlation between level of income, education, age, or gender, and the likelihood of spending money on installing a greywater recycling unit

Data Presented

Awareness

The data we collected showed that exactly half of the people surveyed had never heard of greywater recycling. This fact illustrates that there is room for education on greywater recycling and water conservation in the southeastern corner of Idaho. Out of the 50% of people who already knew of greywater recycling, only 40% of them said they would "likely" share the information from the brochure (Figure 17.) Further analysis of the data showed that 70% of the residents who had never heard of greywater recycling were inclined to "definitely" or "likely" share information about greywater recycling.

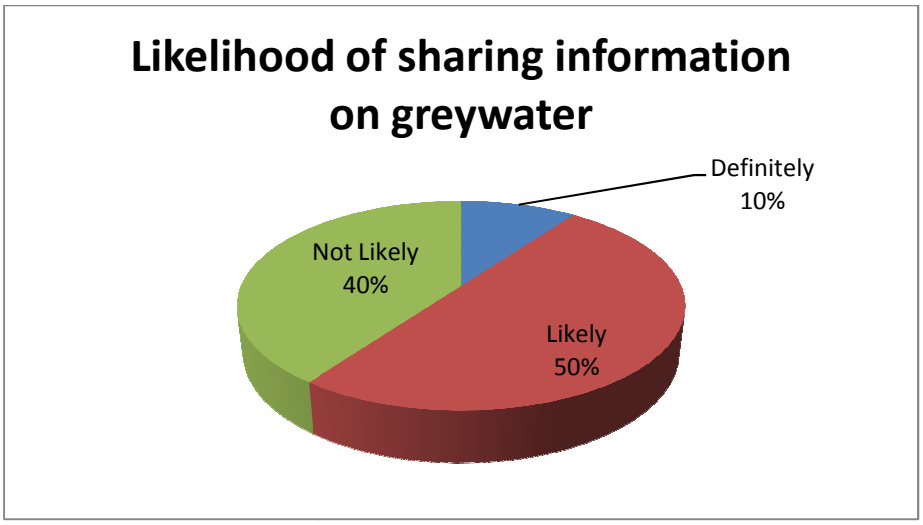


FIGURE 16. Surveyed People and the Likelihood of Sharing Information on Greywater

Reasonable cost determination

The residents surveyed were told that a greywater recycling system costs in the vicinity of $350.00 with a yearly upkeep cost of $15.00. They were then asked if they thought if that was a reasonable price. Eighty percent of the residents felt that this was reasonable (Figure 17.)

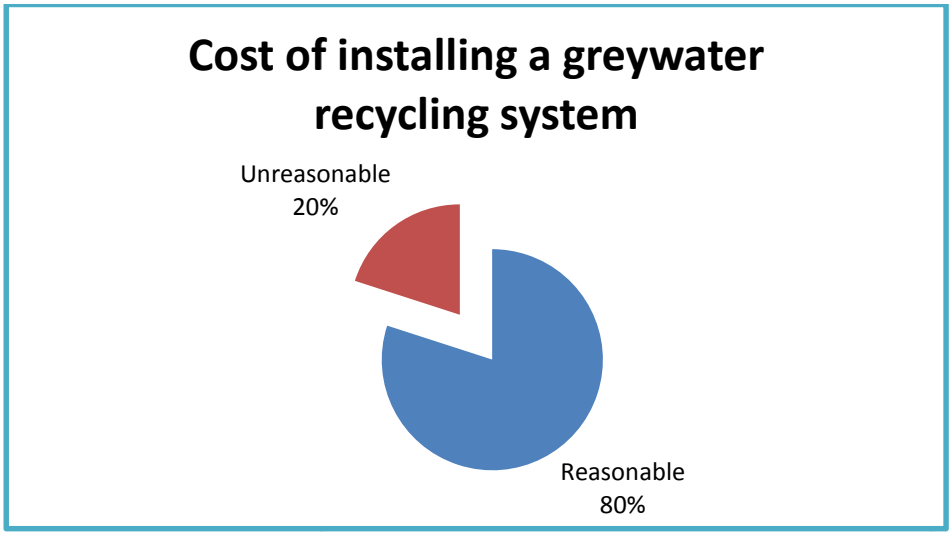


FIGURE 17. Surveyed Southeast Idaho Residents Views on the Costs of Installing a Greywater Recycling Unit

Likelihood of installation

Residents were surveyed to see if they would be interested in installing a unit if it meant that they could enjoy a possible savings of 30% off their water bill. The results show us that 30% of people would be probably, and 10% would very likely install a system if this were the case (Figure 18). However we get a total of 60% of people who were not sure or not likely to install. Upon further investigation we can see a correlation between the people who were "not sure" or "not likely" to want to become involved with greywater recycling, and people that lived on wells or septic systems. Seventy-one percent of people surveyed who were not interested in installing or "not sure" were actually located in areas where they utilized septic systems and/or private wells.

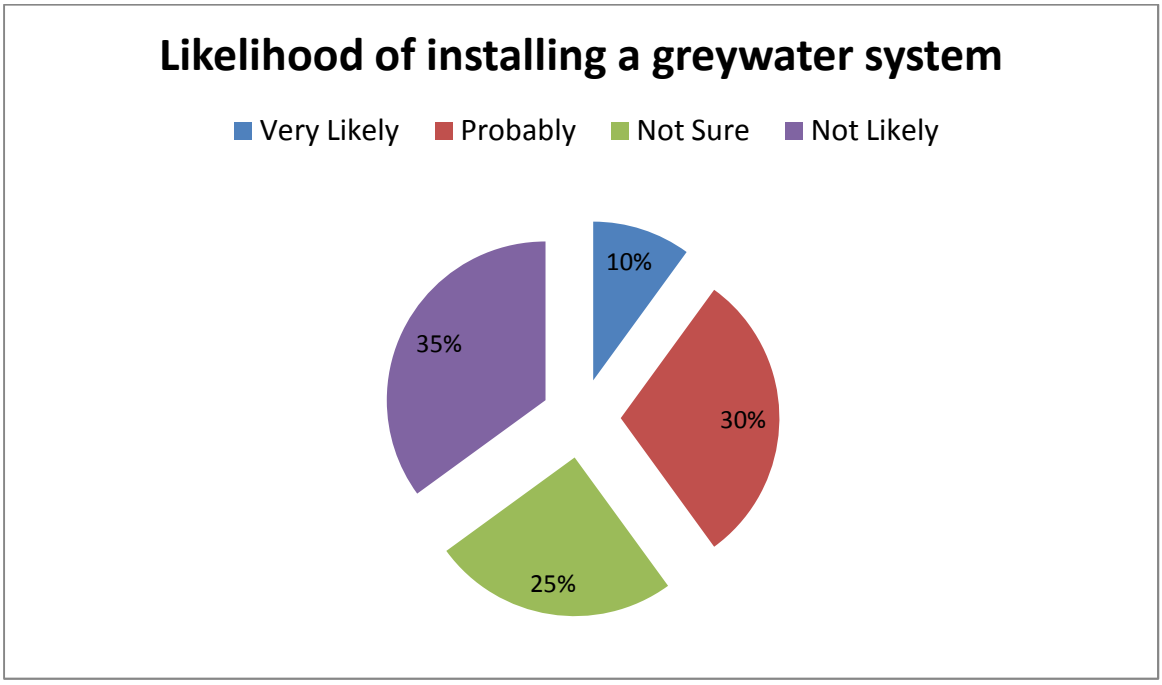


FIGURE 18. Likelihood of Surveyed Southeastern Idaho Residents Installing a Greywater Recycling System

Wells and septic systems. Out of the residents surveyed who live on well water, five out of seven people (71%) were either "not sure" or "not likely" to install a greywater recycling unit (Figure 19). The people surveyed that were "not sure" wrote in some reasons as being: need to do more research, too much effort, time involved and installation. Out of all the people on wells or septic systems only one person stated that they would "probably" install a system.

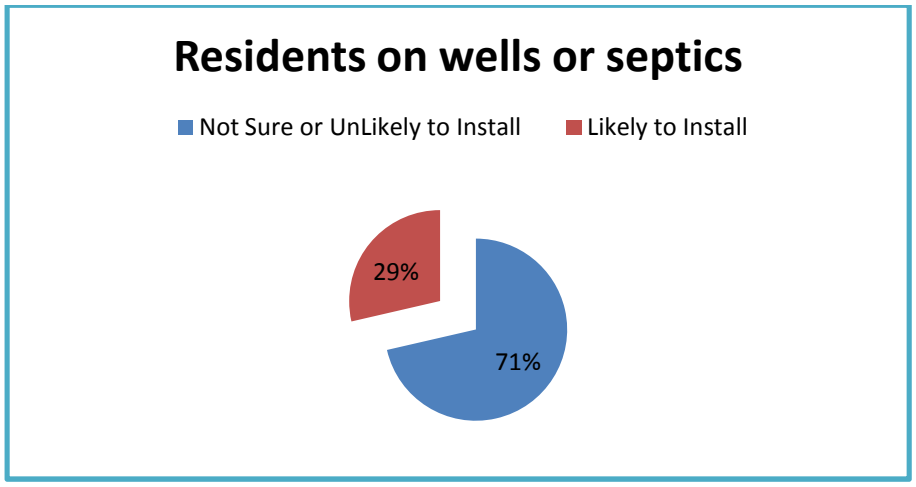


FIGURE 19. Southeast Idaho Residents on Private Wells and/or Septic Systems and the Likelihood of Installing a Greywater System

Water bill costs. Residents of southeast Idaho were asked to estimate their average monthly water bills. Fifteen percent of people surveyed paid nothing for water (Figure 20). Fifty percent of people have a monthly bill of over $75.00 as shown in table 5 below. The information further shows the likelihood of people wishing to install a greywater recycling unit based on their monthly water bill. One can see a direct correlation here. The higher the water bill the more likely a homeowner was to install a system. Residents with water bills under $75.00 were also less likely to be interested in installing (Table 6).

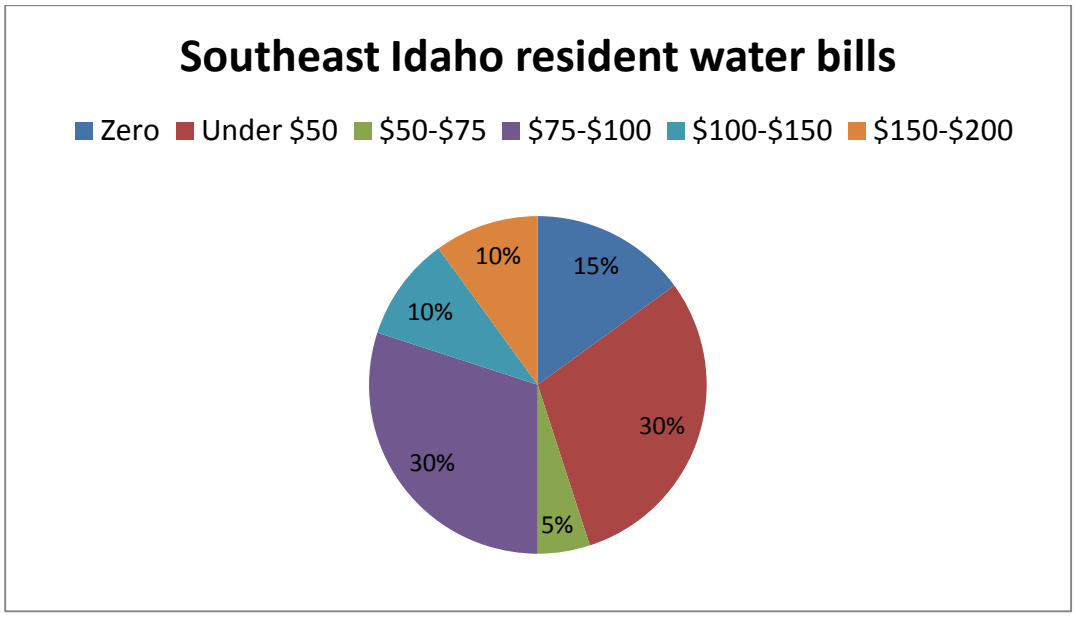


FIGURE 20. Southeast Idaho Resident Average Monthly Water Bill

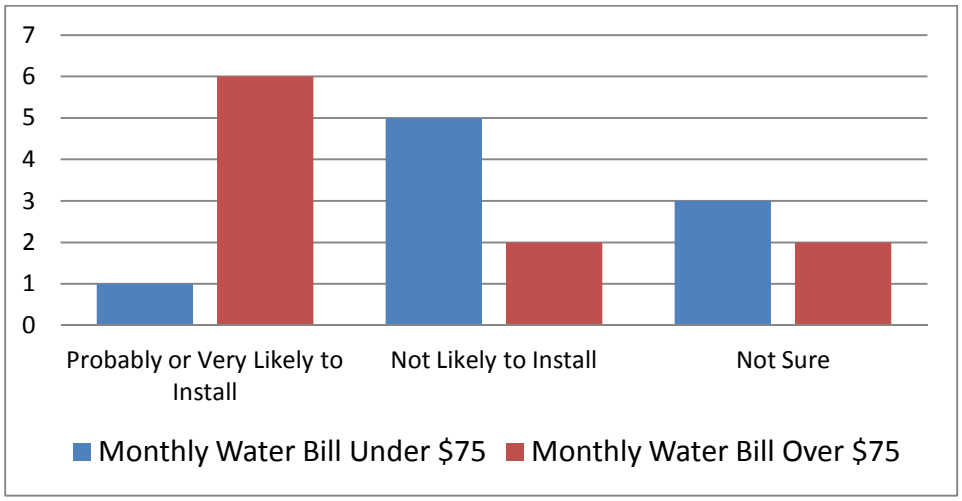


FIGURE 21. Average Monthly Water Bill of Surveyed Southeast Idaho Residents and the Likelihood of Greywater System Installation.

Correlations between age, gender, salary or education. The survey asked each person their age, level of education, annual salary range, and gender. The majority of folks felt that the cost of a system was reasonable. The people who did not feel it to be reasonable fell in the middle income bracket of $25,000 to $40,000 per year. Strangely enough this was also the population that was found to be most likely to install a system (Figure 22).
Figure 23 shows us that eight out of the thirteen (69%) people surveyed who had "some college," felt that the cost to install a greywater recycling system was reasonable. The other 31% did not. Forty-six percent of residents with "some college" also said they were "likely" to install a system sometime in the future. Of the 3 people surveyed who had high school diplomas, or the equivalent of, all of them felt that even though the cost of a system was indeed reasonable, that they would be unlikely to ever install one. Southeastern Idaho residents who had acquired a four year degree, or higher, show a 67% likelihood of installing a greywater system sometime in the future. The same number felt the cost was indeed reasonable.

When the subject of age and gender comes up we can see a definite correlation. Figure 24 illustrates a gender correlation for women. Seven out of nine (77%) women aged 18-55 felt that the systems were of reasonable cost and five of them would be likely to install a system. Furthermore there were no men under the age of 55 years that felt the cost was "unreasonable." If fact half of the group of men aged 18-55 said

they would be likely to install a system if it would save them money on their water bill. We see a trend in the older population of men and women aged 55 and older. Seventy-two percent of this population is not likely to ever install a system, even though 83% felt the cost was indeed reasonable.

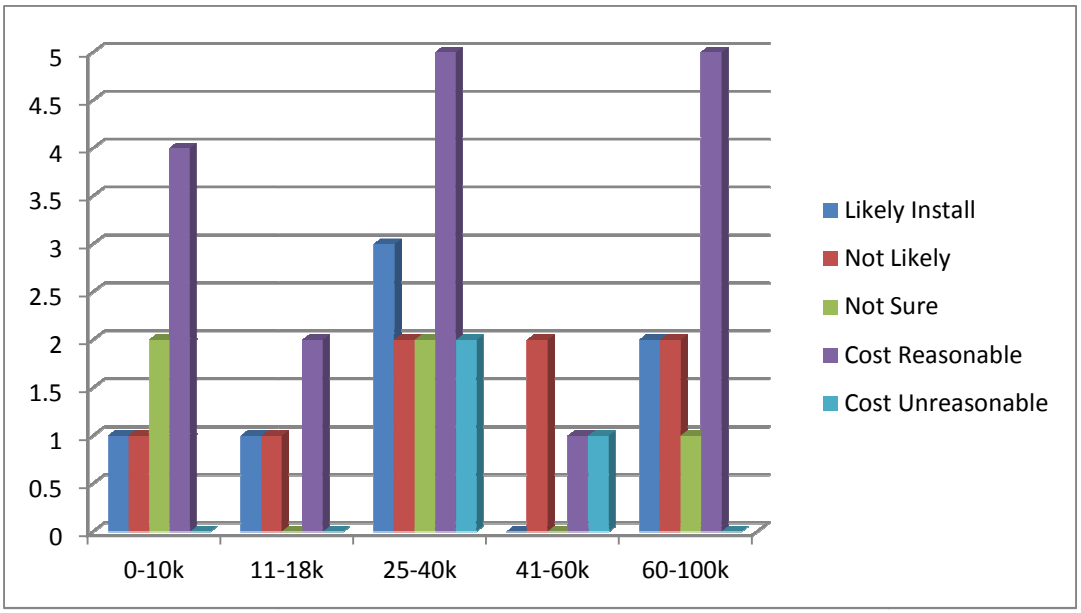


FIGURE 22. Salary in Relation to Cost and the Likelihood of System Installation.

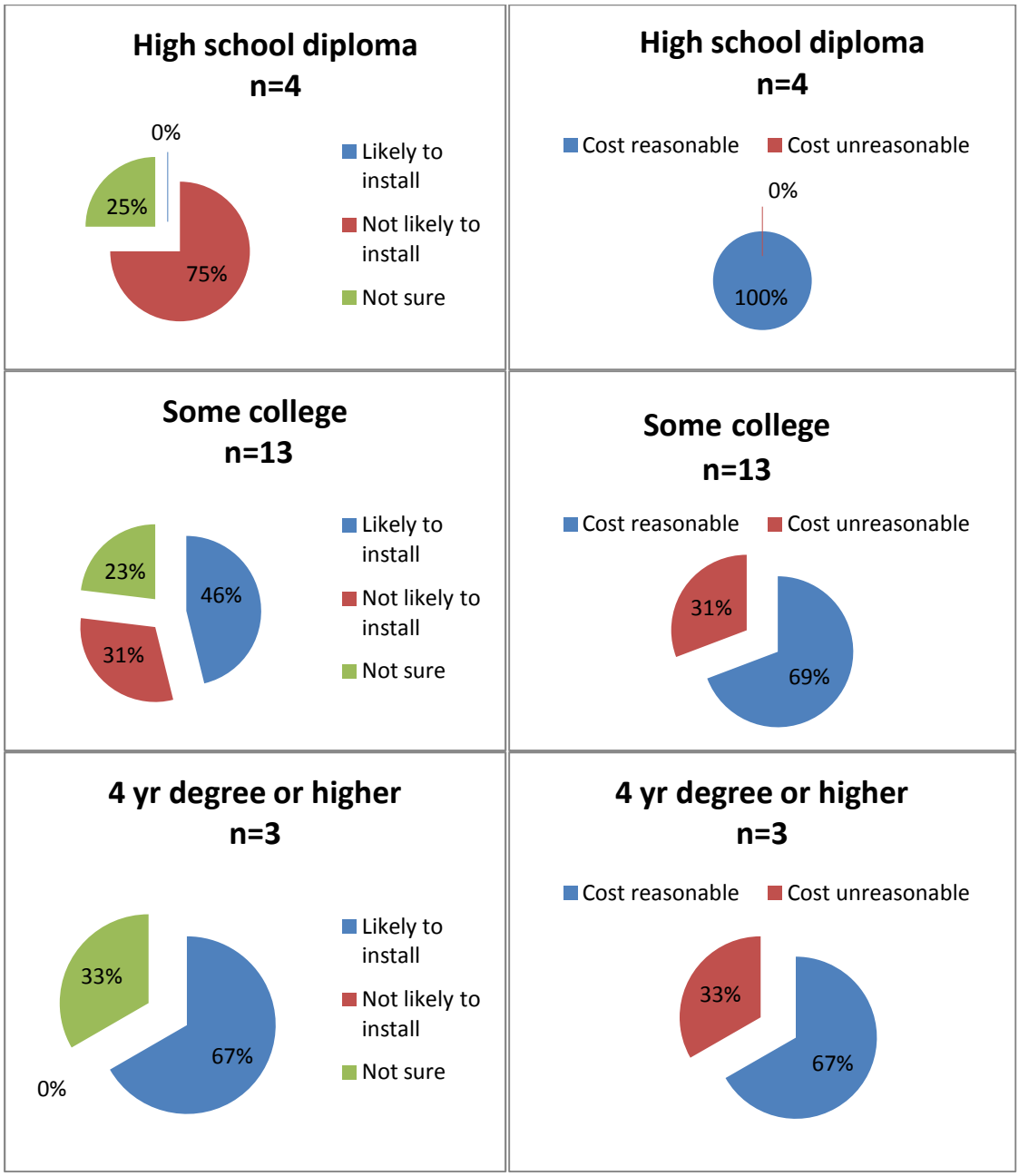


FIGURE 23. Education in Relation to Cost and Likelihood of System Installation

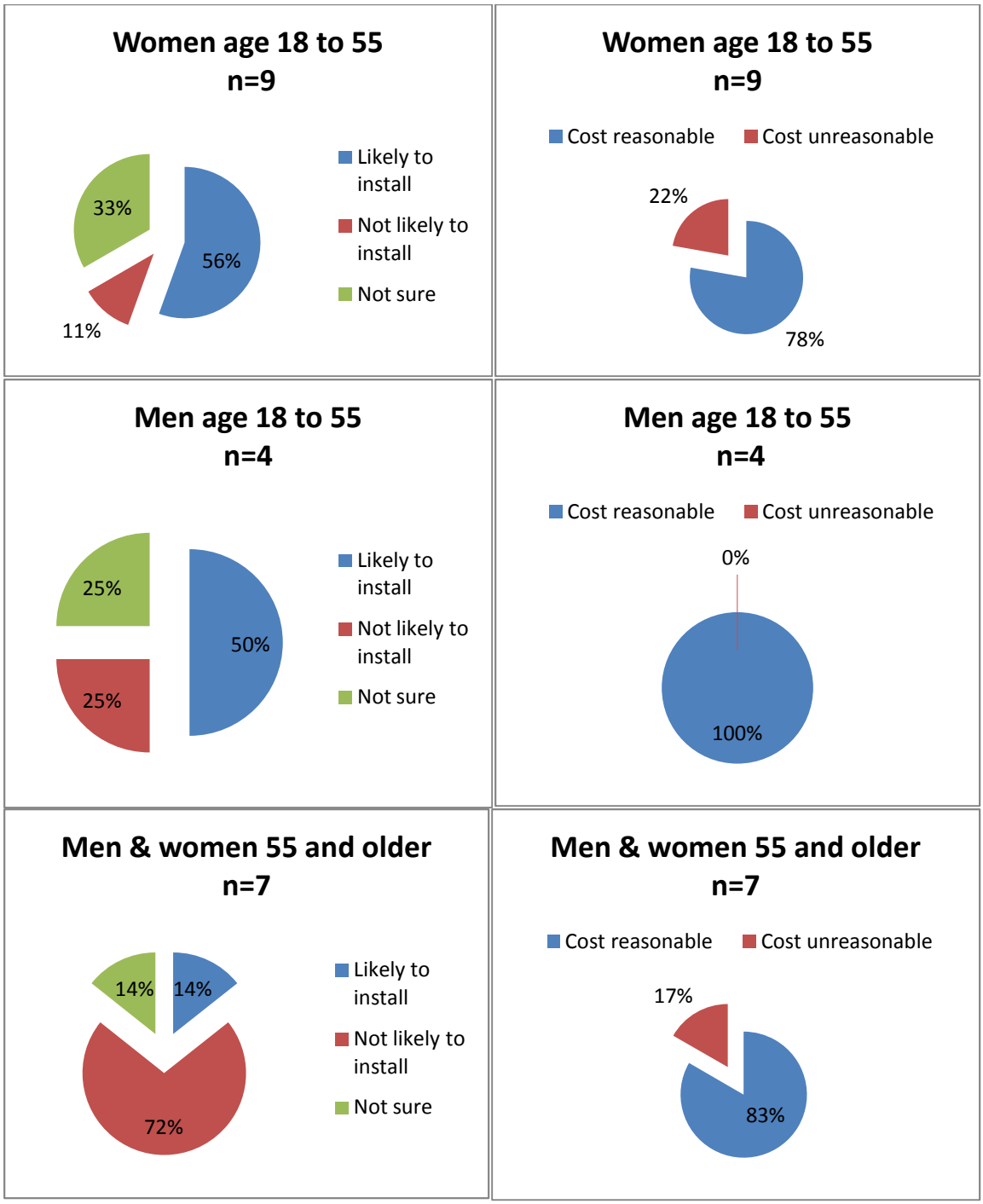


FIGURE 24. Gender and Age in Relation to Cost and Likelihood of System Installation.

Discussion

Residents on a private well do not pay for water. This question was included as part of the survey to discover if the cost of city water could be a motivating factor in water conservation. Money is often a motivating factor in getting people to change habits. This was a very small scale survey. Nevertheless having 71% of residents on well water not being interested in greywater recycling could quite possibly be due to the fact that they do not pay for water. The survey showed that people with higher water bills were more likely to take an interest in greywater recycling and to be more apt to share the information they learned with others.

Of the three people surveyed who were "not sure" about taking part in greywater recycling, they noted on their paperwork that they were either not the owner of the home, that they needed to investigate the methods more thoroughly, or that they really had no need to do so as they were on well water.

Several people who stated that they were "not likely" to install a unit, left notations on the survey in the space provided. Some reasons cited were that they were happy with what they had, they had no need for one, or that they were retired. One gentleman wrote in that he felt the cost should be even lower.

Conclusion

Water is a precious resource in southeastern Idaho and beyond. There are many statistics to support the fact that fresh water is scarce and not becoming more available. With our world's ever growing population, and the move towards urbanization, the demands for fresh water are increasing in cities. Agriculture, pollution, modern industry, and climate change are also taking their toll on the earth's fresh water supply. One small way to aid in conserving water is through greywater recycling.

Greywater has been proven to be healthy for plants and soils. Greywater can recharge groundwater supplies. It helps extend the life of septic systems and wells. Recycling slightly used water to flush toilets or water thirsty yards in arid landscapes can save homeowners money on their water bills. There are very few hazards involved with greywater recycling. Simple precautions and best practices are smart to follow in order to have success and to keep people and pets safe from greywater contamination. There have been no reported cases of a person getting sick from greywater.

Greywater recycling can be done on a small budget for those who are concerned about costs. There are many Do-It-Yourself methods which can be implemented. There are also more elaborate methods for the homeowner who wants to become more involved in this

water-saving process. There are local resources available regarding the permit process. Many private companies and organizations are out there that have guides for the Do-It-Yourselfer in order to support them and get them started on greywater recycling. Although this method of water conservation and water reuse has been practiced around the world for years, there are many people in the United States who have yet to hear about it.

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