Graywater Reuse for Irrigation: Benefits and Potential Hazards

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Definition of Graywater

Graywater has been defined as all wastewaters generated in the household, except toilet wastes (Ingham 1980). A more recent definition is: "all flows exiting an urban building" (Winward et al. 2008a). Thus graywater includes wastewater from bathroom sinks, baths, showers, laundry facilities, dishwaters and sometimes, kitchen sinks. Due to the various household uses of water, graywater gets its name from its less than pristine appearance, and has led to an informal definition of water based on its appearance (Information Box 1).

Graywater can be further classified as "low load" and "high load" in terms of organic strength or concentration. Low load graywater does not contain kitchen and laundry wastewater which tends to have more organic contaminants than other household sources of graywater (Friedler 2004).

Quantities of Graywater Generated by Households

In terms of total water usage per person in a household, the amount of graywater produced vastly exceeds the amount of potable water consumed. Potable water consumption varies with a number of factors including gender, health, exercise and climate, but in general is between 2 and 4 l of water per person per day.

The total water use for families also varies depending on a number of variables and can range from 20 to 30 l per person per day in poorer areas, to over several

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Information Box 1 Colloquial definition of water based on its appearance

Type of water	Colloquial name
Potable water	White water
Household wastewater	Graywater
Toilet waste/sewage water	Blackwater

Table 1 Per capita in-house usage (Loh and Coghlan 2003)

Appliance	Residential premise (single household)	
	L/house/day[a]	L/person/day
Bath and shower	198	66
Washing machine	141	47
Sub-total graywater	339	113
Toilet	124	41
Taps (includes kitchen)	140	47
Total in-house	603	201

[a]Based on 3 people per house

hundred liters per day for more wealthy individuals. However, an estimate of 120–240 l per day might be considered "normal" usage. The amount of graywater generated from various household practices is shown in Table 1. This data was generated in Sydney Australia, and is based on a household consisting of three people. In the scenario presented, 339 l of graywater were produced daily, whereas approximately 223 l per day of water were utilized for garden and lawn irrigation, car washing and swimming pools (Sydney Water 2005). Note that the largest source of graywater is from bathing and showers. Thus it is estimated that reusing graywater for irrigation could save between 50,000 and 100,000 l of potable water per household annually (NSW Government 2008).

Uses of Graywater

For most homeowners, the obvious and most simple way to reuse graywater is to pipe it directly outside and use it for irrigation of gardens, lawns, ornamental plants or fruit trees. The mechanisms for moving graywater from the home to the targeted area for irrigation can be as simple as manual bucketing for small quantities of graywater, or as complex as the construction and use of sophisticated diversion systems (Fig. 1a, b, c). These systems are designed for immediate use of graywater, since graywater should not be stored for longer than one day prior to use. If graywater is to be utilized for purposes other than irrigation, such as toilet flushing, then additional treatment to improve the water quality is necessary prior to such usage. Note also that since using graywater for irrigation may be limited seasonally, then there

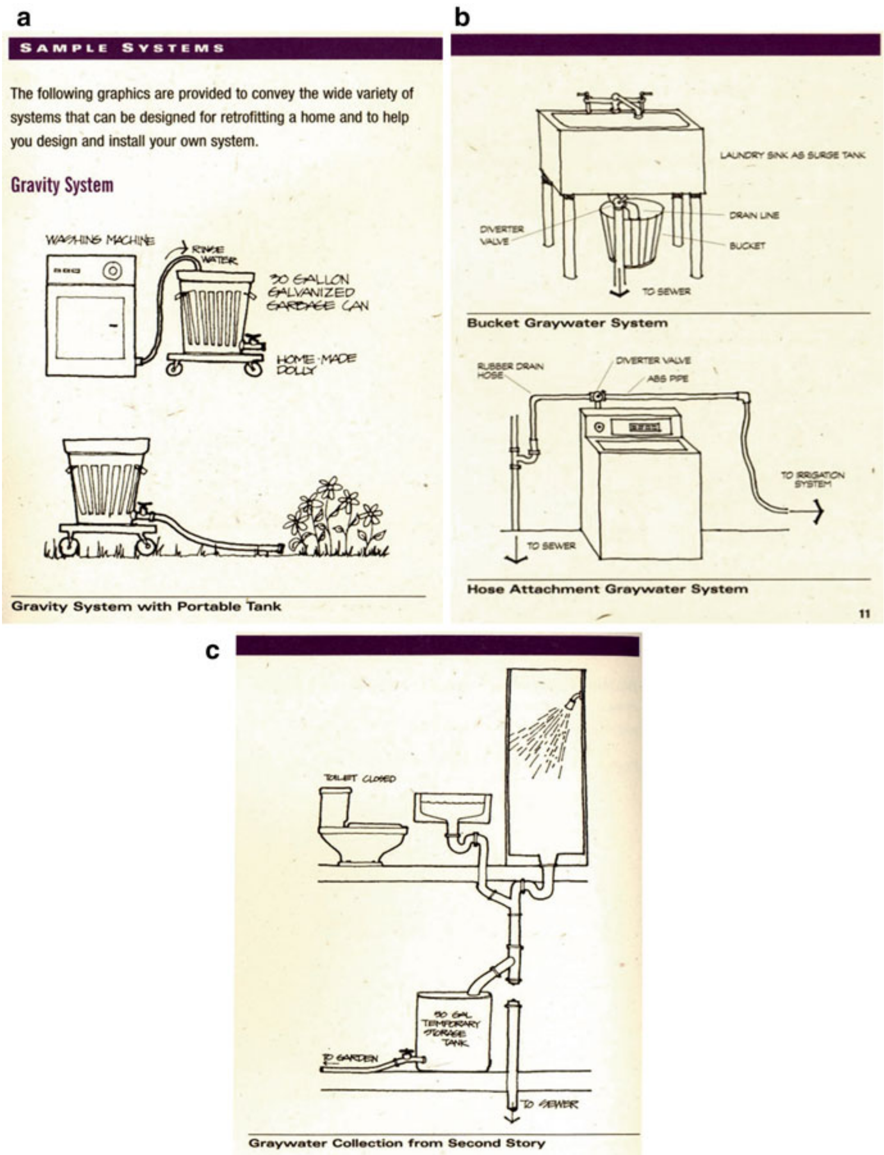

Fig. 1 Sample systems for diverting graywater: (**a**) gravity systems; (**b**) hose attachment system; and (**c**) collection from second story

must be easy mechanisms to cut off the graywater diversion systems, and resupply the graywater sources back into the sewer or septic system when necessary. When irrigating with graywater, the water can be supplied via flood irrigation or drip irrigation (surface or subsurface), but never via a sprinkler system. Basic guidelines for using graywater for irrigation are shown in Information Box 2.

Information Box 2 Guidelines for safe use of graywater

Always
Follow any local city, county or state regulations
Apply graywater directly to or into soil, not via a sprinkler system
Select garden-friendly detergents that are biodegradable and low in phosphorous, sodium, boron and chloride
Select washing detergents that are low in salt – consider using a powder concentrate, or a liquid washing detergent
Monitor plant and soil response to graywater irrigation
Occasionally irrigate with drinking water to leach salts from the soil
(only necessary during extended periods of zero rainfall)
Mark and label all pipes and use signs to indicate graywater reuse
Use graywater on well-established plants, not seedlings or young plants
Never
Reuse toilet or kitchen wastewater
Reuse graywater during rainfall events that could cause runoff
Reuse graywater from the washing of diapers or contaminated clothing
Reuse graywater when a resident is sick, e.g. has diarrhea
Reuse graywater generated by cleaning the laundry or bathroom, or when using hair dye or other chemicals
Reuse graywater to top up rainwater tanks or swimming pools
Store untreated graywater
Reuse graywater on plants that will be eaten raw or where fruit has fallen to the ground and could be eaten
Allow direct contact or ingestion of the graywater
Reuse graywater so that it flows into the streets or down storm water drains
Let graywater go beyond the property boundary and cause a nuisance to neighbors
Use graywater for irrigation of plants that only thrive in an acidic pH soil
Use graywater in households where immunosuppressed individuals are present
Use graywater on root crops that are not cooked prior to consumption
Store graywater for extended periods

Adapted from NSW Government (2008)

Microbial Content of Graywater

The primary reason that there are regulations or concerns about using gray water is that gray water will contain small concentrations of pathogenic microorganisms. These organisms get into gray water when the potable water comes in contact with pathogens from hand washing, washing fruits and vegetables, and other household activities. It is difficult or impossible to test water for all potentially hazardous pathogens, both as a result of gaps in our ability to culture different organisms and the time and expense associated with testing. Instead, we generally test for indicator organisms. If these indicator organisms are not found, this typically means that other pathogens will also not be present. When graywater is collected and used without inputs of black water from toilet waste or sewage water, human pathogenic microorganisms are reduced in concentration but not totally eliminated. Several studies have shown that graywater may contain pathogens, as well as indicator organisms such as total and fecal coliforms. Graywater from kitchens in particular can be a source of bacterial pathogens such as *Salmonella* or *Campylobacter* that are frequently associated with meat products such as chickens (Ericksson et al. 2002). This is one reason why kitchen graywater should be excluded from graywater irrigation sources. However, shower or bath water can also be a source of microbial contamination, particularly for families with small children (Rose et al. 1991). Other sources of contamination can be the washing of soiled diapers, or hand washing after toilet use. The microbial content of graywater produced by a family of two adults is shown in Table 2. These data suggest that while indicator bacterial concentrations can be high, pathogenic bacterial concentrations are lower. A risk assessment of the hazards posed by microbes in graywater was conducted by Ottoson and Stenström in 2003. Their study concluded that risks were low, but that microbial risks from viruses, in particular rotavirus, posed the greatest hazard. Overall, to reduce the risk of illness from exposure to microbial pathogens, it would be prudent to restrict irrigation with graywater to non-food crops, to limit graywater irrigation to crops where the edible portion does not come into direct contact with soil, to stop graywater irrigation a week or two prior to harvesting crops, or treat graywater prior to use on food crops. Studies on reclaimed water (treated water from wastewater treatment plants) have shown rapid die off of pathogens when applied to soil surfaces (Hamilton et al. 2006; Manios et al. 2006; Sidhu et al. 2008). It may be that pathogens entering the soil system through graywater use may also experience rapid die off resulting in minimal risk.

Table 2 Microbial characteristics of graywater produced by a family of two adults

	Arithmetic mean	Geometric mean	Minimum value	Maximum value	Range
Total coliforms (CFU/100 mL)	8.03×10^{7}	2.39×10^{7}	6.60×10^{5}	2.10×10^{8}	2.09×10^{8}
Fecal coliforms (CFU/100 mL)	5.63×10^{-5}	6.95×10^{4}	3.20×10^{3}	8.56×10^{6}	8.55×10^{6}
Fecal streptococci (CFU/100 mL)	2.38×10^{2}	1.21×10^{2}	8.00×10^{0}	9.00×10^{2}	8.92×10^{2}
S. aureus (CFU/100 mL)	0	0	–	–	–
P. aeruginosa (CFU/100 mL)	1.99×10^{4}	2.92×10^{3}	2.00×10^{2}	1.57×10^{5}	1.57×10^{-5}
Coliphages (PFU/100 mL)	<1	<1	–	–	–

From Casanova et al. 2001

Nutrient and Organic Content of Graywater

Physical and chemical characteristics of a ‘typical’ graywater from a single household are shown in Table 3.

The second concern about using graywater for irrigation is its’ effect on soils and plants. In terms of plant nutrients, graywater contains useful amounts of essential elements including nitrogen and phosphorus, as well as magnesium and calcium. By knowing the approximate nutrient concentrations and the volume of graywater applied, the amount of added nutrients can be calculated, and taken into account if additional fertilizers are added. However, graywater will also typically contain salts such as sodium that can build up in soil following long term continuous irrigation with gray water. Sodium in particular is a potential hazard for long term use of graywater due to its high content in laundry detergents (Information Box 3). In soils, excess sodium expressed as the sodium adsorption ratio (SAR) can lead to poor plant growth as well as soil structure problems that reduce water infiltration. Water with SAR values > 6 can cause increased soil sodicity.

The organic content of graywater is not normally a problem unless kitchen sink graywater sources are also included in the irrigation water. Such organic content arises from food waste and greases, and ideally should not be utilized for graywater irrigation.

Table 3 Physical and chemical characteristics of a ‘typical’ graywater from a single household

Parameter	Mean value	Range
pH	7.5	5–8
Turbidity (NTU)	76	20–140
Biological Oxygen Demand (BOD) (mg/L)	65	41–85
Total Organic Carbon (TOC) (mg/L)	49	30–65
Total dissolved salts (mg/L)	35	15–112
Hardness (mg/L)	144	112–152
Alkalinity (mg/L)	158	149–198
Phosphate (mg/L)	9	4–35
Sulfate (mg/L)	23	12–40
Ammonium-N (mg/L)	0.75	0.1–3.2
Nitrate (mg/L)	1	0–5
Total N (mg/L)	1.7	0.6–5.2
Chloride (mg/L)	9	3–12

Adapted from Rose et al. (1991), Casanova et al. (2001), NSW Government (2008), Winward et al. (2008a, b)

Information Box 3 Typical sodium adsorption ratios of detergents

	Sodium adsorption ratio (SAR)	
Graywater type	Mean	Range
Laundry (powder detergent)	9.2	1.2–52.1
Laundry (liquid detergent)	1	0.02–4

Higher ratios mean that a higher percentage of soil adsorption sites are filled with sodium
Adapted from NSW Government (2008)

Management of Soils Irrigated with Graywater

The key potential hazards of using graywater for long term continuous irrigation are soil build up of salts and sodium. There are two ways to reduce the potential for excess salts to build up in soils irrigated with gray water: salt leaching and use of soil amendments. Salt leaching involves inputs of water other than graywater to flush excess salts and sodium through the soil root zone. In areas with seasonal rainfall, the rain itself may be sufficient for the leaching process. In arid regions, occasional irrigation with fresh water can be used to reduce salt concentrations. If symptoms of plant stress occur, such as loss of tree leaves, you should water soil thoroughly with fresh water. Tap water is generally much lower in salts than gray water and can be used to flush excess salts through the soil profile. Soil amendments are also excellent tools to reduce soil sodium and alkalinity issues. These include the use of gypsum, calcium sulfate, or elemental sulfur that becomes oxidized and reduces the soil pH. The addition of an organic mulch or compost can also be beneficial in reducing these problems.

Treatment of Graywater

Many states prohibit graywater use (see regulatory section). Some, such as California, allow it for only certain applications. If homeowners chose to treat graywater to reduce risks from disease-causing microorganisms, a variety of techniques can be utilized that vary greatly in terms of their complexity and sophistication. Ultimately the choice of treatment may be determined by the answer to issues and questions shown in Information Box 4.

For single- family homeowners, treatment technologies tend to be relatively simple. For multiple-owner complexes such as an apartment complexes, larger volumes of graywater can be collected and subjected to more complex technologies. Simple technologies typically consist of settling tanks, or filtration units.

Settling tanks, as the name implies allow for collection of graywater, from which solids and large particles settle out, while greases, oils and small particles float to

Information Box 4 Issues to consider prior to designing and building graywater treatment technologies

Issue:	Quantity of greywater to be treated?
Response:	Smaller volumes need simple technologies to be cost effective
Issue:	Types of contaminants within the greywater?
Response:	Disinfecting bathroom graywater may not be a critical as kitchen graywater
Issue:	Planned use of the graywater
Response:	Greywater irrigation of food crops will require more treatment than for trees or ornamentals

the surface and can be skimmed off. To do this, 55 gallon plastic garbage bins can be used. Chlorine granules can be added to the graywater as a microbial disinfectant, and the chlorine level checked using simple kits provided by swimming pool supply stores.

Filtration can be as simple as a cloth mesh bag tied over the end of a hose, which will filter out lint and hair. Commercial filters are also available utilizing activated charcoal or cellulose. These can be gravity fed or pressurized. Slow sand filtration units can also be easily built using sand within a 55 gallon drum. Essential features of the unit include: (i) a perforated plate on top of the sand to ensure even distribution of greywater over the sand; (ii) a drain pipe at the bottom of the drum connected to a concrete funnel at the bottom of the drum; and (iii) large stones at the bottom of the filter to encourage drainage. Typically a slow sand filter unit will consist of a two feet depth of sand, beneath which are shallow layers of the stone, followed by medium gravel and pea gravel. Slow sand filtration will remove pathogens, suspended solids, organics and turbidity. Maintenance of such units includes periodic removal of the top most portion of the sand (one to two inches).

For treatment of large quantities of graywater very sophisticated technologies can be utilized including constructed wetlands or membrane bioreactors. Of these, membrane bioreactors have been shown to produce the highest quality water for irrigation (Winward et al. 2008b).

Summary

The safe use of graywater for irrigation of food and non-food crops is cost-effective and environmentally sound, provided appropriate guidelines are followed. Large scale use of graywater, particularly in communities in arid regions has the potential to save millions of gallons of potable water, while also supplying nutrients essential for plant growth. In an urban setting, graywater use for irrigation is an effective water conservation practice.

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