An Overview of Graywater Collection and Treatment Systems

R. Y. Alkhatib[1], L. A. Roesner[2], and C. Marjoram[3]

[1]Graduate research assistant, Urban Water Infrastructure Laboratory, Civil Engineering Department, Colorado State University, Fort Collins, CO 80523; PH (970) 491-2838, FAX (970) 491-7727; email: khatibry@engr.colostate.edu
[2]Professor of Urban Water Infrastructure Systems, Civil Engineering Department, Colorado State University, Fort Collins, CO 80523; PH (970) 491-7430
[3]Graduate Research Assistant, Urban Water Infrastructure Laboratory, Civil Engineering Department, Colorado State University, Fort Collins, CO

Abstract

The use of graywater is becoming more and more common, especially in areas where water resources are scarce. A wide range of graywater systems exists; from simple collection to complex collection/treatment. Currently, the market recognized this trend and need for using graywater. So, some manufacturers made some effort regarding innovating engineered graywater collection/treatment systems.

This paper examines some of the graywater collection and treatment systems available in the market for use in a household and in some other buildings along with their weaknesses and strengths. Several systems were selected to show the diversity of systems available and the big picture. Designers of the systems tried to comply with the guidelines set by authorities on the use of graywater such as underground irrigation, no cross connections with potable water system, vented and sealed tanks, no human contacts, etc. At the commercial level, toilet flushing did not receive as much attention as landscape irrigation in the US. However, several successful cases for using graywater in toilet flushing were found in other countries like Germany, Australia, and the UK. The more complex systems are utilized for toilet flushing. Treatment units such as sedimentation, filtration (coarse filters and sand filtration), aeration, and disinfection were encountered. Biological treatment existed where multi-house or multi-user collection systems exist (e.g. hotel and multi-storey residential building).

Based on that overview, simplicity, flexibility, effectiveness, reliability, and cost are criteria that should be considered while designing a graywater system. These criteria were used in designing a graywater system in a single household in Fort Collins, CO. The system involved continuous recycling and aeration. Further system modifications included assessing the level of filtration and disinfection needed to maintain an effective system. Preliminary investigations showed acceptable levels of indicator organisms. Emphasis has been placed on microbial quality since local boards of health are concerned with human contact and exposure to enteric pathogens.

Introduction

The rule has always been "Necessity is the mother of invention". As a result of the water scarcity problem, people are innovating ways to conserve and recycle water. The need for water is the main factor that triggered the use of graywater as one way to lower the potable water demand. However, other factors exist such as environmental and economical considerations. People have been using graywater for a long time without an official permit. Many official authorities started being realistic by investigating the issue and organizing the process of using graywater by issuing guidelines or regulations for the graywater use. Manufacturers realized the importance of the issue and therefore started innovating graywater diversion and/or treatment systems to comply with the guidelines and the regulations set by official authorities while at the same time satisfy the needs of users.

Literature Review

Graywater Definition. As per the Uniform Plumbing Code, 2000 edition, appendix G, graywater is defined as "untreated household wastewater which has not come into contact with toilet wastes. Graywater includes used water from bathtubs, showers, bathroom, wash basins, and water from clothes washing machines and laundry tubs. It shall not include waste water from kitchen sinks or dishwashers".

Graywater Uses. Numerous studies listed a number of graywater possible applications. The most common and acceptable applications are the uses in landscape irrigation and toilet flushing. In the US, the only use encountered was landscape irrigation. The application of graywater in toilet flushing has been encountered in some European countries, Japan, and Australia.

Using Graywater in the US. The water saving potential of using graywater has been recognized by several US states. Jeppesen (1996) reported that the western states of the US and Japan are the world leaders in graywater reuse. The official allowance of graywater usage is not a new issue in the US. During the drought period of 1977-1978 and as an incentive to use graywater, the State of California provided tax relief to those who chose to install graywater systems. In 1989, the first graywater regulations in the US were introduced by Santa Barbara, California (CSBE, 2003).

There are no federal regulations concerning the use of reclaimed Water. Every state carries the burden of setting guidelines or regulations for reclaimed water reuse. Some states went beyond those limits by setting guidelines or regulations for graywater use. As of 1994, twenty-two western states of the USA allowed the direct re-use of untreated domestic graywater by sub-surface watering of ornamental gardens and lawns (Jeppesen and Solley, 1994). Subsurface irrigation; a minimum distance to the highest groundwater level; and sealed and vented tank with a label are few regulations commonly encountered in the graywater state regulations. Subsurface irrigation is mandated in most of the states to prevent human contact with untreated

graywater. The Arizona Department of Environmental Quality allows the surface application of graywater provided the following conditions are satisfied (other conditions apply) : 1) Graywater is not used for irrigating food plants, except for citrus and nut trees; 2) Standing water is minimized; 3) Graywater does not originate from water used to wash diapers or similarly soiled or infectious garments unless graywater is disinfected before irrigation; and 4) Spraying is not used. No federal guidelines or regulations exist for the use of graywater. Graywater systems have been addressed by the Uniform Plumbing Code (UPC) since its 1994 edition (CSBE, 2003).

Graywater Concerns. The main concerns in graywater use are those associated with its quality. Graywater characteristics reported by several studies indicate that graywater has to be considered as dilute sewage because it has all constituents of raw wastewater (Christova-Boal et al. 1996). Despite the fact that graywater contains only a minimal amount of fecal contamination, high numbers of fecal indicators were reported in several studies. In some graywater studies, the numbers of fecal indicators reported were in the range found in raw wastewater.
The chemical quality of graywater becomes of special importance when considering graywater for landscape irrigation.

Graywater Collection/Treatment Systems

As mentioned previously, the use of graywater is becoming more and more common. Some people are utilizing graywater without having any formal collection or treatment system. For example they merely have their washing-machine water drained directly into their backyard for reasons like reducing the frequency of emptying their septic tank and reducing the amount of potable water needed for irrigation. In order to make a graywater reuse system practical and acceptable, treatment prior to reuse would be necessary (Rose et al., 1991). Rose et al. (1991) mentioned that the major concerns appear to be turbidity, microbial concentration, and the potential presence of pathogens. Different treatments are available including storage, aeration, sedimentation, filtration, biological treatment, and disinfection.

The market has recognized this trend of using graywater and thus has engineered graywater collection/treatment systems. Health concerns are still considered the main obstacle. The systems are either solely diversion systems or diversion/treatment systems. Manufacturers have been trying to satisfy the guidelines and the regulations set by official authorities while at the same time get the acceptance from users. Therefore, the design process is controlled by the guidelines/regulations and by the user needs/convenience.

For States like Arizona, California, and New Mexico; the use of graywater is legal. However, there are some guidelines that restrict its use including the need for a permit, limiting surface irrigation, prohibiting spray irrigation, and not allowing other graywater uses. Most of the graywater systems (diversion and treatment) were designed in light of such guidelines or regulations (different from state to state and

from country to country). For examples, most of the commercial systems adopt subsurface irrigation as the irrigation method to satisfy the requirements of official authorities. NSW Department of Health in Australia issued accreditation guidelines for the domestic graywater treatment systems (DGTS). The guidelines are intended to provide the manufacturers with the minimum requirements required to have a domestic graywater treatment systems (DGTS) accreditted. Such guidelines will be used by a third party (independent testing agency) for the consistent assessment of a manufacturer's DGTS. Satisfying those guidelines over a period of 26 weeks will lead to a final issuance of a certificate of accreditation by NSW health to a DGTS manufacturer for a period of 5 years (NSW, 2005). Mandatory analysis is to be performed for BOD_5, suspended solids, thermotolerant coliforms, and free chlorine (if used as disinfectant).According to these guidelines, a DGTS is defined as a domestic graywater treatment system designed to store, treat, and disinfect graywater or components of graywater to the standards specified in the NSW Health Accreditation Guidelines so that it may be applied to a surface or sub-surface irrigation area, and/or reused for toilet flushing and laundry use in the household. Local authorities cannot approve the installation of a manufactured DGTS unless it is accredited by the NSW Health Department.

Five systems have been selected as examples. However, other systems do exist. The example systems were selected on the basis of their diversity. They were chosen to show the big picture and the big variations in the existing systems in terms of components and method of treatment.

1. **Earthstar Graywater System.** It is a graywater system marketed by Gaiam Real Goods. The system main components are a 55-gallon tank, sand filter, automatic float switch, and a pump. When the water reaches a specific level in the tank, the automatic float switch triggers the operation of the pump to start evacuating the tank to the yard. The system is intended for irrigation use. For the sand filter cleaning, an automatic backwash is applied every two months. The system is simple in its operation. The most expensive parts are the pump and the sand filter. The user will carry the burden of backwashing the sand filter. Settlement and sand filtration are the treatment methods used in this system. Sand filtration is known to be effective in removing a significant portion of the turbidity. The system in its current status seems to be oriented to the disposal side not to the reuse side.

2. **Clivus Multrum System.** The system looks like a wet well in pumping stations (Figure 1). The main components are dosing basin, a submersible pump, and level control float. No treatment is included. The system is intended for irrigation use. The irrigation system adopted in this system is an underground irrigation using either an irrigation chamber (a half-round pipe 8-12" diameter) or wood made irrigation trough. To ensure a constant depth overall the irrigation chamber, the pump is programmed to work when the amount of water in the dosing basin is enough to create a 1-1/2 inches of water depth in the irrigation chamber. The main advantage of the system is that there is no contact between the users and the graywater. Therefore, the only safeguard in the system is the minimum-contact

safeguard. No treatment takes place (except for settling). The system takes advantage of graywater whenever graywater is available; not whenever it is needed, which again puts it in the disposal side; not the reuse side. Another advantage is the idea of distributing water evenly in the irrigation chamber. However, for such even distribution to occur, the type of soil irrigated should be taken into account.

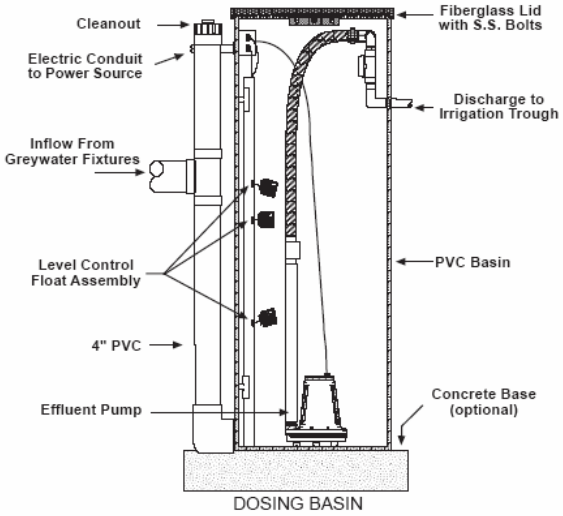
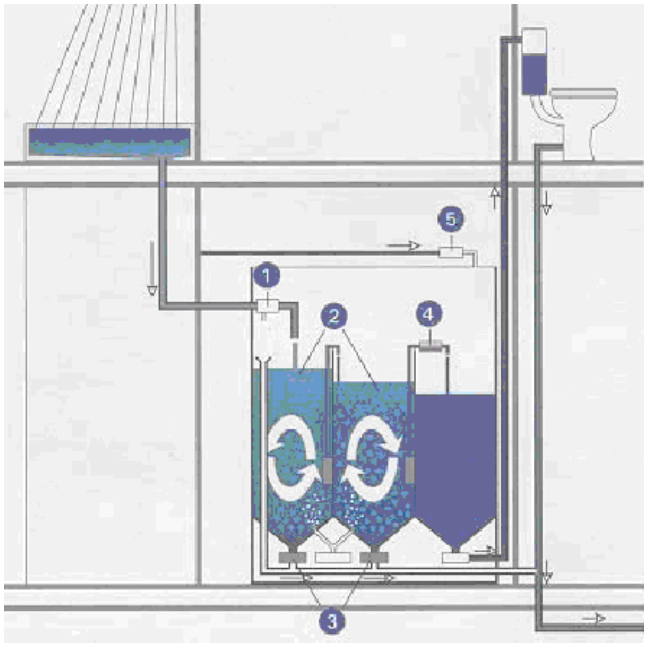


Figure 1. Clivus Multrum Graywater System
Source: http://www.clivusmultrum.com/greywater.html

3. **A graywater system in Germany.** That system was found in the German Water Sector Report. It utilizes graywater for toilet flushing. The system looks like a real treatment plant but in a miniature scale (Figure 2). It includes coarse filter, two aerated chambers, UV disinfection unit, storage tank, and backup potable water feed if the graywater is not enough to feed the toilets. Comparing it to the real wastewater treatment plants, one can see that the coarse filter functions as the bar screen in the WWTP. The two chambers act as primary and secondary treatment tanks. Aeration is also included in the tanks. A final disinfection is included using the UV unit. Finally, there is a third tank that works as a storage reservoir to feed the toilets. The following treatment sequence exists in the system:
    a. **Filtration:** to remove coarse items such as hair, threads, and lint. Backwashing is applied by a jet pump. Residues drain off into the sewer line.
    b. **Biological cleansing:** Two chambers are used; primary and secondary.
    c. **Sludge extraction**: Sludge accumulated in the biological cleansing process is fed into the sewer line.
    d. **Disinfection:** After leaving the secondary tank, the graywater goes into a UV disinfection unit.
    e. **Water storage reservoir:** A third tank exists after the UV unit to store water. The toilet takes water from this tank.
    f. **Drinking water feedback:** In the case that graywater quantity- is not enough for toilet flushing, drinking water is fed into the third tank.

Obviously, the main disadvantages of the system are the costs and the complications associated with running the system. A household owner will not have the capability and the time to take care of such complicated treatment sequence.



1) Filteration, 2) Primary & secondary cleansing chambers
3) Sludge extraction, 4) UV disinfection unit, 5) Tap water backfeed

Figure 2. Graywater System for Toilet Flushing, Germany
Source: http://www.umweltbundesamt.org/wsektor/wasserdoku/english/frameset_e.html

4. **Greywater Saver.** An Australian owned and patented graywater reuse system was also investigated. The system is called "Greywater Saver". In this system, graywater is collected for use in irrigation (irrigation trenches). The system is one of the simplest in operation and construction. No storage is provided. The only treatment used is a mesh basket filter. The system is also so flexible in diverting the graywater to the sewer system by the use of Push-Pull valve.

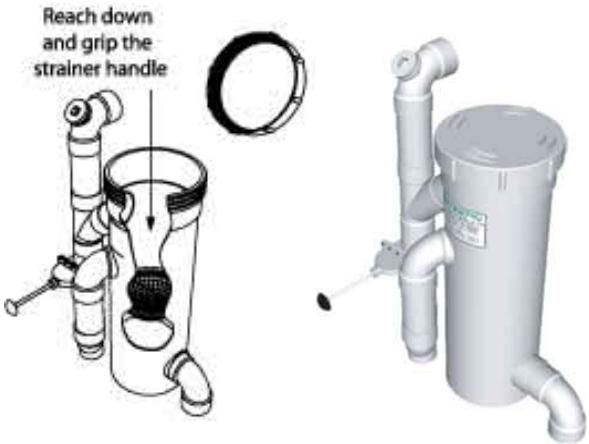


Figure 3. Greywater Saver
Source: http://www.greywatersaver.com/index.htm

5. **California Graywater System.** A system recommended by the State of California. Almost all other state-recommended systems have the same components. The main components are:
    - Sealed, locked, and vented tank
    - A warning sign for unsafe water existence
    - 3-way valve to divert the flow to wastewater stream if needed
    - Subsurface irrigation
    - An overflow connected to the sewer system

Not treatment is included. The only safeguard is the no-contact policy.

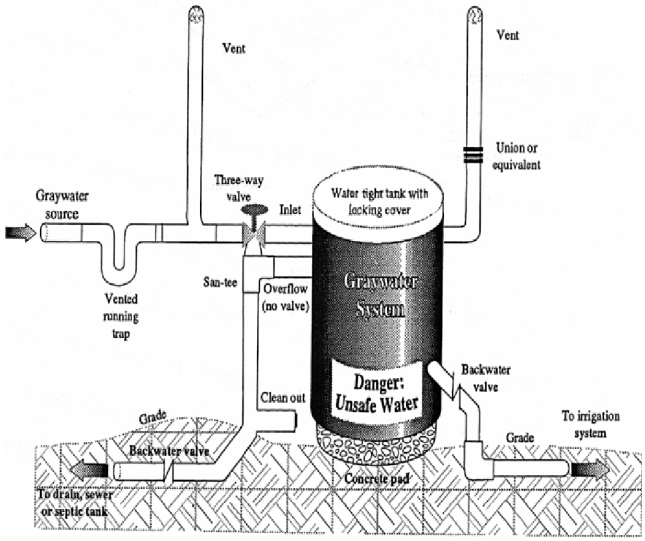
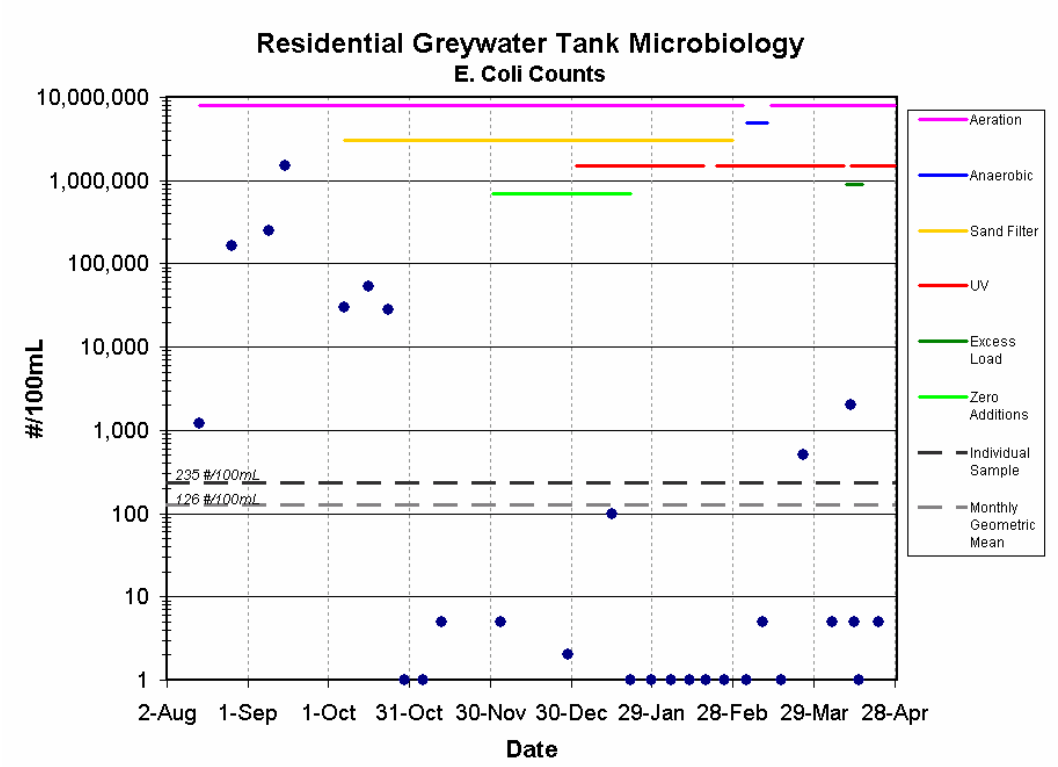


Figure 4. California Graywater System
Source: California Revised Graywater Standards (website)

6. **System Designed at HHS at Colorado State University.** Researchers at Harold Short Lab at Colorado State University are investigating the effect of different treatment techniques on graywater quality. A household inhabited by two adults was retrofitted with a graywater system that collects graywater from shower, bath sink, and laundry. Aeration, sand filtration, and UV disinfection are among the techniques investigated. Figure 5 shows some of the research results with respect to *E. coli* content. Preliminary investigations indicated that a graywater system adopting aeration, UV disinfection, and continuous recycling led to satisfactory results regarding graywater quality.



Figrue 5. *E. coli* counts for a graywater treatment system in response to different treatment techniques

Table 1 shows a summary for the graywater systems presented previously.

Table 1. Summary for Presented Graywater Systems

System	Components	Use	Storage	Aeration	Filtration	Pumping	Disinfection
CSU*	Tank, sand filter, UV.	Irrigation	300 gallon tank	Yes	Sand filter	Yes	UV
Earthstar	Tank, sand filter, automatic float switch, and a pump.	Irrigation	55-gallon tank	No	Sand filter	Yes	No
Clivus Multrum	Dosing basin, level control float, and submersible pump.	Irrigation	Dosing basin Approx. 250 gal	No	No	Yes (submersible pump)	No
German (for toilet flushing)	Coarse filter, two sedimentation chambers, UV, pump, and a storage tank	Toilet flushing	Yes	Yes	Coarse filtration	Yes	UV
Greywater Saver	Small collector, strainer, pull-push valve.	Irrigation	No	No	Coarse filtration through mesh basket filter (strainer)	No	No
State-designed systems	Tightly covered tank, trap, vents	Irrigation	Yes	No	Yes/No	Typical No, but can be applied if needed	No

* A system designed and operated by Harold Short Lab graduate students at CSU

Discussion

The extent of treatment is different from each manufacturer. A wide range exists; ranging from simple collection of graywater without treatment to more complex systems that simulate the real treatment plants but on a miniature scale. The more complex systems are utilized for uses other than irrigation (e.g. toilet flushing). Typically, the minimum treatment is to use coarse filtration or mesh screens to remove large objects like hair, threads, and lint. Many of the systems surveyed tend to be disposal systems; not reuse systems. Most existing graywater systems in the US are very simple; e.g. gravity drain from washing machine or graywater collection system. This tends to be more of a disposal system. Although biological treatment has been ruled out by several researchers due to imbalance in nutrients and non-conventional COD/BOD ratio, several other cases showed that it worked effectively in reducing the BOD and turbidity in graywater. The main problems associated with the biological treatment are its high cost, comlexity to the homeowner, and its reliance on microorganisms which makes the process sensitive to any changes in the environment.

Some systems have surge and storage tanks. The volume of such tanks is a controversial issue. If economy is to be solely considered, then larger tank size should be adopted to accommodate all graywater quantities generated in the household. On the other hand, in terms of water quality the residence time should be minimized since. Storage of graywater beyond 48 hours leads to the depletion of DO and potential aesthetic problems (Dixon et al., 1999). Al-Jayyousi (2003) reported that counts of total coliform and fecal coliforms increased from 10^0–10^5/100ml to above 10^5/100ml within 48 h. Mustow et al. (1997) recommended that graywater should not be stored for more than 48 hours.

It should be noted here that despite the existence of treatment systems in the market, a survey conducted by the NPD Group (1999) revealed that the majority of graywater reusers did not store (82%) or treat (93%) their graywater before use. This means that there is not enough guidance on using graywater.

The market needs a system that is capable of collecting, storing, treating, and applying graywater. For a homeowner, simplicity, flexibility, and cost are important issues to consider. For regulating authorities, effectiveness and reliability are crucial issues that need to be satisfied in order for the system to be approved.

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