

**Graywater Reuse in Other Countries
and its
Applicability to Jordan**

**Center for the Study of the Built Environment
(CSBE)**

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1.0	Introduction	3
1.1	Water Scarcity in Jordan	4
1.2	What is Graywater Reuse.....	5
2.0	Graywater Reuse in Other Countries	6
2.1	Technical Aspects	7
2.2	Legislation	14
3.0	Issues about Graywater Reuse.....	18
3.1	Graywater Quality.....	18
3.2	Effects on Plants.....	19
3.3	Keeping the Plants Healthy	20
3.4	Effects on Soils.....	22
3.5	Effects on Human Health.....	22
3.6	Effects on the Environment	23
3.7	Irrigation.....	23
3.8	Guidelines.....	24
4.0	Graywater Reuse in Jordan	25
4.1	Historical Water Conservation Practices in Jordan	25
4.2	Current Uses of Graywater in Jordan	25
4.3	Relevant Issues Particular to Jordan	28
4.4	Current Legislation in Jordan Regarding Graywater Reuse	31
4.5	Economic Factors.....	32
5.0	Conclusion	33
6.0	References	34
	Appendix I Selected Lists of Plants that both Tolerate and do not Tolerate Irrigation by Graywater	38
	Appendix II CSBE Preliminary Graywater Guidelines	41

1.0 Introduction

In September 2002, CSBE received a grant from the Ministry of Planning to investigate the reuse of graywater in a domestic context, and determine how such techniques could be applied in Jordan. The project consists of 3 components;

A. Investigation of existing graywater practices and experiences in other countries, including technical, social and economic factors that may have a bearing on the implementation of graywater reuse schemes in Jordan.

B. Interaction with a selection of up to 10 graywater schemes that are being designed or carried out in Jordan, and provision of technical assistance to them at both the design and implementation stages. The results and performance of these schemes will be used to assess the viability of graywater reuse in Jordan and to report on issues particular to the country.

C. Provision and distribution of information on graywater reuse, based on experience gathered during the project. A workshop and consultations will be held with interested parties, and a set of Graywater Reuse Guidelines will be developed, specifically for Jordan, with technical information on how to set up and operate a simple graywater system.

The project deliverables include:

- Report on graywater reuse in other countries;
- Assessment of graywater reuse schemes in Jordan;
- Guidelines on the reuse of graywater in Jordan.

All project reports and publications will be made available in Arabic and English on the CSBE web site at the completion of the project.

This report summarizes the findings on graywater reuse in other countries.

1.1 Water Scarcity in Jordan

Jordan does not have enough water. The kingdom has a scarce enough resource to begin with – no major rivers and minimal rainfall – but the abnormally sharp rise in population (from about 400,000 in the 1920s to 5.2 million in 2001, to a projected 9.2 million in 2020) (Hashemite Kingdom of Jordan 2002) has left Jordan with an increasing gap between requirements and available supply.

The projected figures for water requirements and supply, developed jointly between the Ministry of Water and Irrigation (MoWI) and the World Bank (WB) (World Bank 2001) are summarized in the following graph.

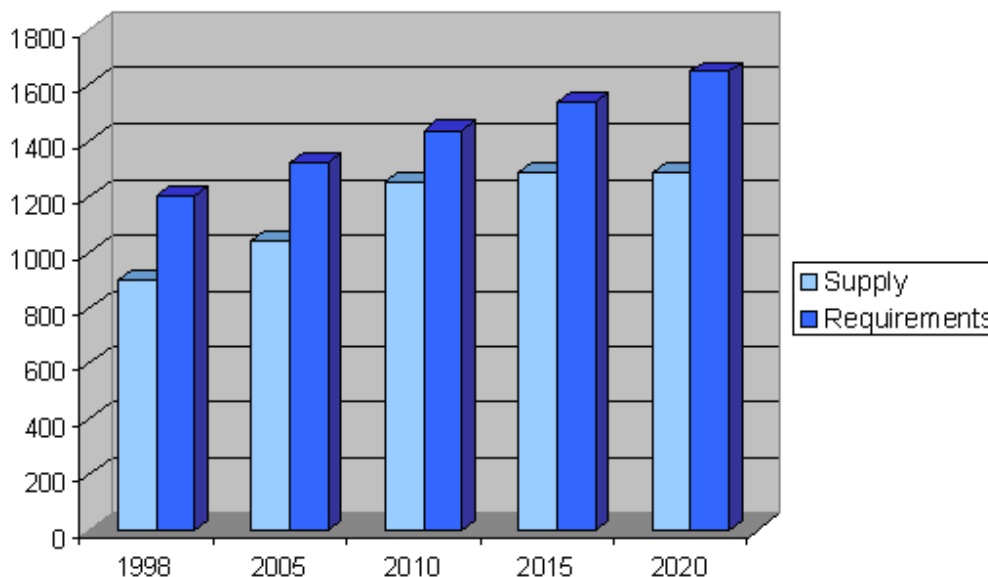


Figure 1.1: Water balance (in million cubic meters), 1998 – 2020 (World Bank Report 2001)

Jordan's water requirements will continue to rise from a figure of 1,205 MCM (million cubic meters) in 1998 to 1,647 MCM in 2020. This is due to increasing population, rising living standards (target per capita municipal requirement of 130 liters/day (l/d) in 1998 rising to 155 l/d by 2020), and an expected increase in industrial requirements. On the other hand, the available water supply will rise only slightly from 898 MCM in 1998 to 1,287 MCM in 2020, assuming that the MoWI's capital investment program goes ahead as scheduled. Among other things, this investment program includes tapping the non-renewable Disi aquifer in southern Jordan to boost the supply to Amman, making available additional water from the Wihdeh and Wadi Mujib dams, and reducing losses by network rehabilitation and other system improvements. Additional water also will be made available as a result of increasing reuse of treated wastewater.

As indicated by the graph, there is an annual shortfall between water requirements and water supplies. The shortfall is currently made up by constraining water available to the irrigation sector, by overdrawing the kingdom's increasingly vulnerable groundwater reserves (essentially borrowing water from our children), and by shortfalls in the amounts supplied for municipal use. The gap between requirements and demand should decrease slightly during

the next decade (due to the implementation of a number of capital programs by MoWI), but will increase thereafter. There is no immediate solution to this increasing gap.

Aside from improving and consolidating the available water supplies at the macro scale, Jordan also needs to improve the efficiency of water use by customers. Examples of such 'demand side management' improvements include the use of low-water-use fittings (faucets, showers, toilets etc), improvement of plumbing codes to ensure better quality plumbing, and the reuse of graywater. Any means of reducing the domestic demand, without impacting quality of life or health, will contribute to the long term water balance. Since the people of Jordan already make do with only a proportion of the per capita water usage in other countries, there is limited scope for demand reduction in the municipal sector. However, there are ways in which households can either reduce their water demand at no real cost to their standard of living, or obtain slightly more benefit from their existing water supply. Reusing household graywater is one of these ways.

1.2 What is Graywater Reuse

Graywater is the output from bathtubs, showers, sinks, floor drains and washing machines, which although no longer clean, is not as contaminated as toilet water. This water can be relatively easily treated on-site for reuse in non-potable contexts such as toilet flushing and garden irrigation. Studies in other countries have estimated that the usable domestic graywater resource easily could amount to 35% of the total domestic demand. Relatively clean graywater is also produced by non-domestic establishments such as restaurants, hotels, schools, and other public buildings.

By intercepting graywater before it goes to the septic tank or the municipal wastewater system, and providing some treatment (in certain cases, no treatment may be required) the water may be reused to irrigate plants. With a little additional treatment, the water also may be used for toilet flushing. Of course, some safeguards are required – these will be discussed later in the report - but provided care is taken as to what enters the graywater in the first place, and the risks to human and plant health are minimized, such reuse is simpler than many people assume.

Graywater reuse is being increasingly widely practiced in other countries, where water is scarce, and often occurs whether legal or not. The technical means of providing safe ways to reuse graywater, and the issues associated with health and environment have been examined in detail by a number of authorities in other countries. Jordan's wastewater policy (Hashemite Kingdom of Jordan 1997) requires that all wastewater be regarded as a resource rather than waste. It is likely that practical, safe ways to reuse graywater can be developed and promoted in Jordan.

This report will examine how graywater is used in other countries, and will discuss some of the issues which may affect the transfer of such technology and practices to Jordan.

2.0 Graywater Reuse in Other Countries

The reuse of graywater is being increasingly practiced in a number of countries, whose water crisis is less critical. A number of these countries have carried out assessments of graywater reuse practices and investigated the technical means of reuse as well as the health and environmental implications. The following are some jurisdictions where information on graywater reuse has been found, and where graywater reuse is currently being practiced.

In the US, no national guidelines exist, as individual states are responsible for their own regulation of water and plumbing. Several states have developed legislation to allow graywater reuse in different circumstances. California was the first state to study and permit the reuse of graywater. Graywater was being permitted in Santa Barbara as early as the 19th Century. A pilot study into graywater reuse in the Los Angeles area was carried out in the 1980s. A Code to regulate the reuse of domestic graywater was issued in 1977 and is currently under revision. In Arizona, graywater is permitted for use in household irrigation. Numerous trials, studies and assessments have been carried out, and reported. Guidelines for graywater reuse have also been prepared. A 2000 study showed that graywater reuse was common in Arizona for irrigation of shade and ornamental trees, even before legislation and guidance were available (Residential Greywater Reuse June 2000).

Studies in Australia published in 1994 and 1997 (Jeppesen and Solley 1984; Anda and Matthew 1997) were carried out to assess the potential for graywater reuse there. The study concluded that significant water savings could be made from the responsible reuse of graywater, provided adequate safeguards were followed. No information regarding the degree for graywater reuse in Australia has been uncovered.

Cyprus has initiated a subsidy program for households that wish to install graywater reuse systems for domestic landscaping and toilet flushing. There is also documentation of graywater reuse at certain hotels and at least one sports facility. Dual plumbing systems have also been introduced to allow the reuse of graywater in toilet flushing (Kambanellas 1999).

Agencies in the UK (Environment Agency, CIRIA and BSIRIA) have published studies on graywater treatment and reuse for toilet flushing (CIRIA 2001). These studies investigated a number of operational pilot plants in various parts of the country, where graywater was captured and treated for use in toilet flushing. Filtration and disinfection were employed to raise the quality of the water to the desired standards. It is estimated that around 150 graywater 'units' were in operation around the country. The studies have concluded that water savings could result but cited issues of reliability and maintenance as needing to be overcome before graywater reuse could be promoted on a more widespread basis. The reports also cite lack of financial incentives due to the cost of graywater systems, and the low cost of water. It is clear that the level of complexity of treatment and operation of graywater systems designed to produce water for toilet flushing is considerably more complicated than for garden irrigation, and leads to increased operation and maintenance costs.

Although legal in Germany, the use of graywater recycling systems has been limited. Instead, rainwater collection for toilet flushing is the favored option, due to the higher quality water available from this source.

Graywater reuse is also practiced in Japan on a scale that ranges from the use of simple hand basin urinals in residential properties that flush the bowl using water from hand washing, to complex recycling systems in office blocks. In Tokyo, graywater recycling is mandatory for buildings with an area over 30,000 square meters or with potential reuse of 100 cubic meters/day (Hanson 1997).

Pilot studies have also been carried out by the Islamic Network for Water Resource Demand Management (INWRDAM) in Palestine and Lebanon, although graywater reuse in these countries is not thought to be widespread (see <http://network.idrc.ca/ev.php>).

2.1 Technical Aspects

The science behind the safe reuse of domestic graywater for irrigation is not difficult. Graywater is captured from the various household sources (sinks, hand-basins, showers, etc), and taken (possibly through a simple treatment system and maybe storage) to a distribution system. In the case of reuse for toilet flushing, often a slightly more sophisticated treatment and storage is required. The components of any type of graywater system may therefore be summarized as follows:

- Sources of Graywater
- Collection of Graywater
- Treatment of Graywater
- Storage of Graywater
- Use of Graywater

Although there are differences in how graywater is used in various countries, there are broad similarities at each stage of the process. The following is a discussion of the main features of graywater sources, collection, treatment, storage and reuse, based on an examination of research and studies conducted in other countries. Much of the following information is taken from the publications listed in the reference section.

2.1.1 Sources of Graywater

Graywater is the term used for normal household liquid wastes, other than toilet wastes. In most countries, the sources of domestic graywater are the same. They include wastewater that flows from baths, bathroom sinks, bathroom showers, and wash basins. Laundry water from clothes washing machines and laundry tubs is also used in many areas. However, this often contains suspended solids and high concentrations of chemicals, and may cause problems if the graywater is to be reused for irrigation. For this reason, the reuse of laundry water sometimes is discouraged.

However, it seems that both bathroom and laundry water are generally less polluted than kitchen sink water, and so are easier to reuse. In many areas (e.g. Arizona, California, and New Mexico) water from the kitchen sink and automatic dishwasher are prohibited from entering the graywater stream since they are high in suspended solids, fats, oils, and grease, and their generally high organic content encourages the growth of bacteria. Also, the high fat and solid content cause problems for filtration and pumping. It is generally recommended that kitchen water be directed to the sewage collection system. However, some sources (www.oasisdesign.net) consider the levels of bacteria in kitchen wastewater to have been vastly overestimated, and that kitchen sink water should not be automatically ruled out for graywater reuse. This remains an issue under debate, and in Arizona, consideration is being given to a lifting of the blanket ban on kitchen water in certain circumstances. In fact, there are examples of long-term use of kitchen sink water with no adverse effects on plants.

Other potential graywater sources include swimming pool water. Collected rainfall runoff is also an important source of reusable water, but is usually of a higher quality than graywater, and is not the subject of this investigation.

2.1.2 Collection of Graywater

Collection of the graywater is simple in concept, but is one of the more practically difficult aspects of reusing graywater. In the simplest case, graywater can be collected simply by

placing a bucket below an open sink drain, and manually transported to the point of use. However, a piped system requires less user intervention and is more ideal from a public health perspective since it eliminates contact between graywater and user. In this case, a plumbing network simply takes the graywater, keeping it separate from the non-graywater, and directs the graywater to a point where it can be stored, treated, or reused.

The details of such systems vary from country to country, but they are generally gravity collection systems that use ordinary plumbing components. In new houses, the installation of such a 'dual-plumbing' system to separate useable graywater from non-useable 'blackwater' is simple and requires little extra expense. However, retrofitting such a dual system into an existing building may require more difficult installation work, depending on the design of the house and the plumbing system.

2.1.3 Treatment of Graywater

There are four reasons why graywater may need to be treated:

- To remove substances which may be harmful to plants;
- To remove substances which may be harmful to health;
- To remove substances which may be harmful to the wider environment;
- To remove substances which may clog the graywater system.

No Treatment

Often, the best solution is to design, install, and maintain a system so that the graywater needs no treatment at all. The reason why graywater is being considered in the first place is due to its relatively clean nature. Many of the substances contained in graywater are not harmful to plants, and some are actually plant nutrients. Some of the substances found in graywater are actually very well treated by a healthy layer of soil, and if human contact between the graywater and humans can be minimized (by eliminating the need for user intervention in the system, and by reducing the possibility of contact at the irrigation stage), then the risk to human health is very small.

Figure 2.1 is a schematic of a simple graywater system that has been successfully operating in Amman for over 2 years. The graywater source has been chosen to minimize the amount of contamination that enters the system – only water from one bathroom – bathtub shower, handbasin – is used. The system is gravity fed throughout, eliminating the need for pumps. The diameter of the irrigation pipe is 50mm, and the distribution holes have been increased to 5mm to reduce the risk of clogging. Not even filtering has been required in this system, although there must be an element of solid material (such as skin and hair) passing through the system. The soil has been able to deal with this organic material, and also with whatever soap constituents may be present. No detrimental effect on the plants has been observed in the 2-year period of operation.

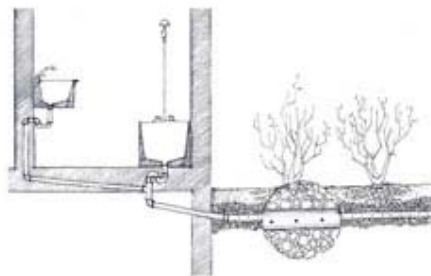


Figure 2.1: Simple graywater system in Amman (Drawing by Hind Hussein)

Filtration

A simple first level of treatment - a filter - may however be advisable in some cases to prevent solid material (hair, lint, food particles) from entering the graywater system. In its simplest form, this could be a stocking or sock filter on the inlet pipe to the storage tank – Figure 2.2, or a more complex sand/gravel media filter as shown in Figure 2.3.

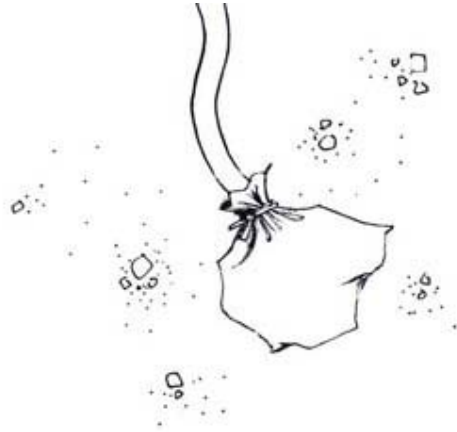


Figure 2.2: Simple sock filter
(Drawing by Hind Hussein after Little 2001)

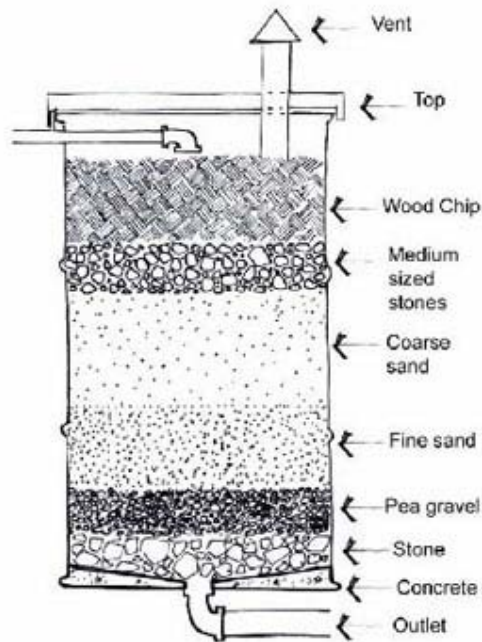


Figure 2.3: Sand/gravel media filter
(Drawing by Hind Hussein after Little 2001)

A number of sources (such as Ludwig 1994 -2000) propose the use of a natural mulch basin filled with stones and organic mulch (leaves, tree bark, etc) to filter and treat the graywater. Rather than containing inert material such as sand, a mulch basin of this type provides a

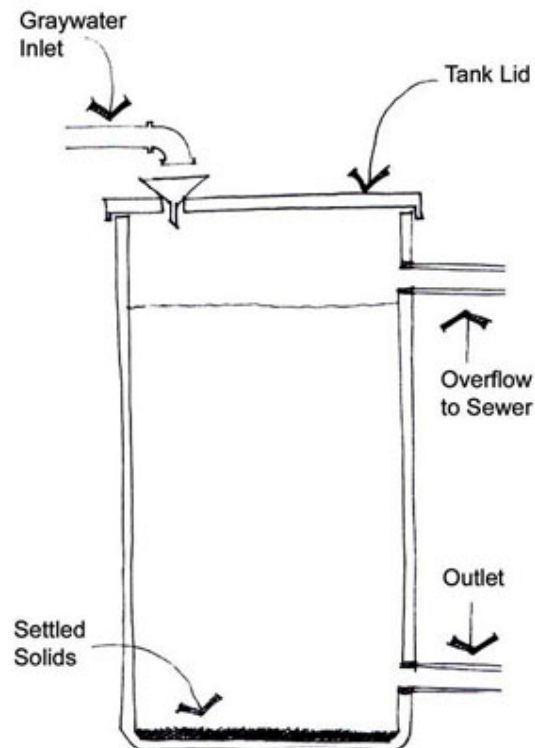
medium for the natural digestion of organic substances, and removes solid material from the graywater.

Similar to this are slow sand filters - shallow layers of stone, medium gravel, and pea gravel beneath a deep layer of sand, or multi-media filters - filled with a variety of media in order of increasing size. Slow sand filters are subject to clogging and very slow percolation rates, and require regular cleaning and replacement of the top layer of media. Some authors therefore do not recommend their use in domestic contexts. Multi-media filters require cleaning less frequently.

Commercially available water filters also are sometimes used for graywater. These include activated charcoal, cellulose, or ceramic cartridges. However, these are generally designed for higher quality water and may require excessive maintenance if used with graywater. If the kitchen sink water were to be used, a grease trap – to remove fats and grease - may be necessary to prevent filter clogging, although this requires a degree of user intervention.

Settlement and Floatation

A settling tank is sometimes recommended as a means of removing solids from the graywater. Substances denser than water will gradually fall out of suspension to the bottom of the tank. On the other hand, grease, oils, and other small particles will float to form a surface scum layer. The remaining liquid can then be reused. A settling tank also has the advantage of allowing hot water to cool before reuse. Figure 2.4 shows a simple graywater settling/storage tank.



**Figure 2.4: Storage or settlement tank
(Drawing by Hind Hussein after Little 2001)**

By contrast, Figure 2.5 shows a complex automated graywater system with storage, filtration and backwashing, pumping and associated controls and valving. This system, discussed in

'Create an Oasis with Greywater' (Ludwig 1994 - 2000) was found to be reliable, but costly – between \$1,100 (about 780 JD) and \$8,000 (about 5,680 JD) to install. Few applications will warrant such complexity and expense.

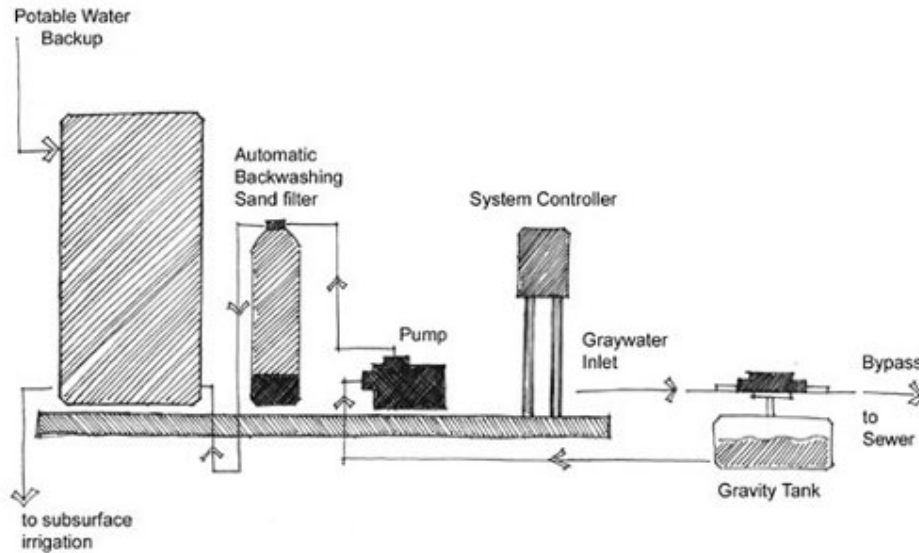


Figure 2.5: Example of an automated graywater treatment system (Drawing by Hind Hussein after Ludwig 1994 - 2000)

Disinfection

Disinfection is often mooted as a necessary method of treatment. The addition of chlorine tablets or iodine to a graywater storage tank (a chlorine concentration of 0.5 parts per million), or the use of UV light or ozone will disinfect the graywater, thus reducing the amount of bacteria present, provided that the bulk of solid or organic material previously has been removed by filtering or settlement. This will have the effect of reducing odors from graywater that has been left standing and has begun to digest. However, unless there is risk of human contact with the graywater – something that should be avoided in all responsible graywater reuse systems – there is no particular advantage to this reduction of bacterial content. Human-borne bacteria cannot survive for long periods outside the human body, and will soon die in the soil. There is no health risk to plants from such bacteria, although ironically, the presence of chlorine or other disinfection agents in the graywater may cause problems to plants and soil. Water disinfected with chlorine should be left at least overnight, to allow evaporation of the chlorine.

Other types of systems of varied complexity also have been noted in the literature, but the evidence consistently points to simpler systems being more reliable, with most complex systems being abandoned due to high maintenance costs, and disinterest by the householder due to the amount of intervention required.

The suitability of the type of system is largely determined by the quality of the incoming graywater, its end use, and the degree of care and intervention desired by the user. The minimal treatment system is perhaps best suited to a user who will take an active interest in controlling what goes into the graywater, and who takes a fairly active role in caring and tending for their own plants. The cleaner the graywater to begin with, the less treatment required. A more complex, catch-all system is more suited to an establishment where less attention is paid to what goes into the graywater, and how it is used. However, this relatively complex system requires more maintenance, and is more expensive.

2.1.4 Storage of Graywater

Differences of opinion also exist with regard to whether graywater should be stored or not. There is a common misconception that stored graywater becomes more and more contaminated. This is because of the odors that may develop through time as the organic content in the graywater begins to digest. Actually, this process of digestion is a form of anaerobic treatment of the graywater, and the resulting water will contain less organic material and generally be 'cleaner'. However, the odors may be an unpleasant side effect and should be controlled by venting the graywater storage tank away from places where the odor would become a nuisance. In many countries, domestic plumbing will have odor traps that are vented to the roof to prevent odors from entering the house through the piping system. However, provided the graywater storage tank itself is sealed, there ought to be no significant odor problem.

Even if the graywater is to be stored for a substantial period of time, some authors consider treatment to be unnecessary, provided odors are controlled. Others, however, recommend it, and suggest filtration to reduce the amount of organic material present, and disinfection to reduce the amount of microorganisms present. Adding two tablespoons of chlorine bleach per 5 liters of water provides one manner of achieving this goal.

Simpler systems will not need storage of the graywater. Direct reuse without storage is favored as it minimizes the problems of microorganism growth and odor. However, even if storage is not required, each graywater system should be capable of handling sudden foreseeable inputs of graywater (for example from a bath being let out, or a washing machine rinse cycle) without overloading or saturating the soil. In these cases, many authors recommend a surge tank – a small facility to allow the flow to surge, while releasing it gradually to the soil. A simple sketch of a surge facility is shown in Figure 2.6.

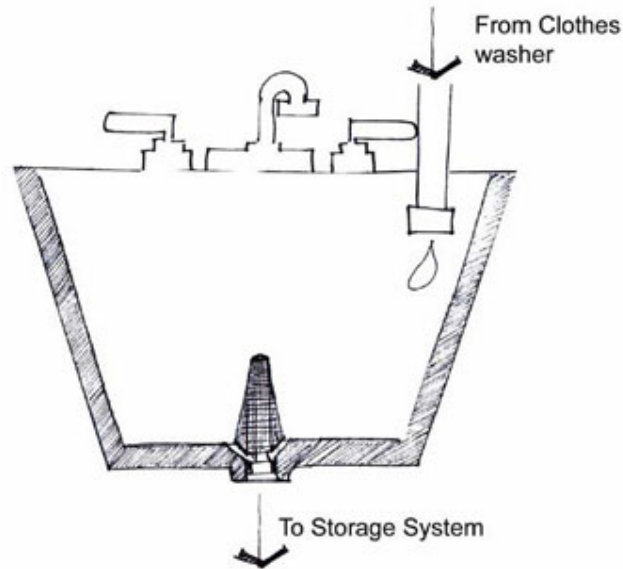


Figure 2.6: Surge tank
(Drawing by Hind Hussein after Little 2001)

Even if no storage is provided, an odor problem may also arise if graywater is allowed to pool in parts of the pipe bends, tanks or other parts of the network. If a graywater system becomes unused for a period of time (for example the householders go on holiday) then there is risk

that pools of graywater in the system will begin to digest anaerobically and cause unpleasant odors. Most sources recommend that all pipes be at a gradient, and that all tank bases, etc be angled, with provision for drainage, so that the entire system can be emptied of water, if necessary.

2.1.5 Use of Graywater other than for Irrigation

As noted above, this investigation concentrates on the use of graywater for household irrigation. However, in some countries, graywater is also used for toilet flushing. A simple way of using graywater for toilet flushing is illustrated in Figure 2.7. This hand basin toilet idea is popular in Japan and is installed in many Japanese homes, as well as in commercial areas. This system incorporates a hand basin at the top of the cistern, with a tap for hand washing. The tap operates automatically when the toilet flushes to simultaneously refill the cistern and to allow hand washing. However, it should be noted that in applications where graywater captured from other household sources has been used for toilet flushing, unpleasant odor and discoloration of the toilet bowl have been reported.



**Figure 2.7: Graywater reuse for toilet flushing in Japan
(Photograph from Jeppesen and Solley 1994)**

In the UK, graywater reuse is not common, but a recent study (Leggett et al. 2001a; Leggett et al. 2001b) estimated that about 150 graywater treatment units were being used to provide water for toilet flushing. This study looked at various collection and storage designs, with disinfection as the main means of treatment, and found that useful water savings were obtained, but that maintenance and reliability issues were significant.

Cyprus is encouraging households to reuse graywater for domestic landscaping and toilet flushing (Kambanellas 1999).

No consensus yet exists regarding the quality of water necessary for toilet flushing. Although there is no contact between the user and the graywater, and the water becomes contaminated upon use anyway, there are concerns over transmission of diseases due to splashing, or as a result of cross-contamination with the potable water supply, which would be required as a backup supply. For this reason, disinfection of the graywater before use is usually recommended.

2.2 Legislation

The following is a summary of the legislative position with regard to graywater reuse in a number of countries. It should not be regarded as exhaustive.

United States

In 1989, Santa Barbara, California was the first locale in the US to introduce graywater regulations. Following that, domestic graywater reuse has started to become legalized in several US states. In the US, regulations concerning water reuse are made by individual states, as there are no relevant federal laws, although the federal Uniform Plumbing Code (UPC) has addressed graywater systems since its 1994 edition.

US - Arizona

In 2001, the Arizona Department of Environmental Quality published regulations for residential graywater reuse. These regulations follow a three-tiered approach whereby systems using under 1500 liters per day must meet a list of reasonable conditions, and are covered by a general permit without the need for the householder to apply for anything. Systems producing over 1500 liters per day require a permit, and those over 13,000 liters per day are dealt with on a case by case basis.

Graywater is defined as wastewater collected separately from clothes washers, bathtubs, showers, and sinks. Reuse of wastewater from a kitchen sink, dishwasher, or toilet is specifically prohibited, although a revision of the regulations due in 2003 may permit the use of kitchen sink water under certain conditions.

The conditions for the private residential reuse of graywater include avoidance of human contact between graywater and soil irrigated by graywater, containment of graywater from a particular residence within the property boundary, and graywater usage only for household gardening. In addition, surface application of graywater may not be used for irrigation of food plants, except for fruit trees, and surface irrigation by graywater should be restricted to flood or drip irrigation. Sprinkling is prohibited. The graywater should not contain water used to wash diapers or similarly soiled or infectious garments, unless the graywater is disinfected before irrigation. Likewise, the graywater should not contain hazardous chemicals, for example from cleaning car parts, washing greasy or oily rags, or disposing waste solutions from home photo labs, or similar hobby or home occupational activities.

The regulations require that graywater systems should be constructed so that if blockage, plugging, or backup of the system occurs, graywater can be directed into the sewage collection system or an on-site wastewater treatment system. The graywater system can include a means of filtration to reduce plugging and extend the system's lifetime.

In addition, any graywater storage tank should be covered to restrict access and to discourage breeding of mosquitoes or other disease bearing insects. The graywater system should not be sited in a floodway and should be operated to maintain a minimum vertical separation distance of at least 1.5 meters from the point of graywater application to the top of the seasonally high groundwater table. Residences with an on-site wastewater treatment facility for blackwater must not change the design, capacity, or reserve area requirements for this facility if installing a graywater system. Any pressure piping used in a graywater system that may be susceptible to cross connection with a potable water system should clearly indicate that the piping does not carry potable water.

These regulations are widely regarded as the most progressive anywhere. The tiered approach makes reuse easy for the ordinary householder and allows for innovation and

flexibility of design. They do not prescribe particular design specifics and follow a performance based approach. The blanket prohibitions ensure the protection of human and plant health.

A booklet containing the text of Arizona's Title 18 Reuse Rules, and some explanatory notes and guidelines are available for download from www.watercasa.org.

US - California

Although the California Graywater Code – CAC (Title 24, Part 5, Appendix J, Graywater Systems for Single Family Dwellings) was regarded as groundbreaking in its time, it takes a very different approach from that of Arizona and is regarded as only partially successful. This code prescribes graywater system designs, and has been criticized for not allowing flexibility and innovation on the part of the user. The code defines graywater as untreated wastewater that has not come into contact with toilet waste. This includes wastewater from bathtubs, showers, bathroom wash basins, clothes washing machines, and laundry tubs, or an equivalent discharge as approved by the local authority. The code does not allow wastewater from kitchen sinks, photo lab sinks, dishwashers, or laundry water from soiled diapers to be considered as graywater.

The CAC mandates that all graywater systems must discharge into subsurface irrigation fields, and sets procedures for estimating graywater discharge volumes and for determining the irrigation capacity of the soil. The code requires soil percolation tests and/or soil analyses as the basis for determining the required area of 'disposal'. This code also sets standards for graywater subsurface drip irrigation systems. The householder therefore must provide significant information to the local authorities before a permit is issued. This acts as a disincentive to graywater reuse and contrasts unfavorably with Arizona's blanket permit.

To reduce possible health risks that can result from the reuse of graywater, residents in California are prohibited from applying graywater above the land surface or discharging it directly into storm sewers or any body of water. In addition, humans must not contact graywater, except as required to maintain the graywater treatment and distribution system, and graywater must not be used for irrigating vegetable gardens.

A detailed analysis of the code and a number of suggested improvements are outlined in the 'Builder's Greywater Guide' (Ludwig 1995-1999), and on the Oasis Design web site (www.oasisdesign.net).

US - New Mexico

New Mexico recently passed a graywater law that is similar in approach to that of Arizona. As of March 2003, householders can install legal graywater systems without applying for a permit. Provided the system meets a short list of reasonable requirements that are similar to those in the Arizona law, it is permissible to install a graywater system under one blanket permit for the whole state.

It is expected that such progressive graywater legislation in New Mexico, along with Arizona, may provide a large enough market to provide a foothold for graywater businesses and system innovation in the southwestern US.

US - Texas

Currently, Title 5 of the Sanitation and Environmental Quality / Subtitle A on Sanitation defines graywater as wastewater from clothes-washing machines, showers, bathtubs, hand-washing lavatories, and sinks that are not used for disposal of hazardous or toxic ingredients (Regulations: Chapter 285: On-Site Sewage Facilities (1999), <http://www.tceq.state.tx.us>). The

Texas State Board of Plumbing Examiners is currently developing rules for the reuse of residential graywater in irrigation and for other agricultural, domestic, commercial, and industrial purposes, to assure that the use of graywater does not damage the quality of surface water and groundwater in the state.

US - Nevada

In Nevada, sewage disposal is regulated under the Nevada Administrative Code (February 1998; see <http://www.weblife.org/humanure/appendix3.html>). Graywater may be used for sub-surface irrigation if approved by the administrative authority. A home owner must obtain a permit from the administrative authority before a graywater system may be constructed, altered, or installed. A system that uses graywater for underground irrigation may be used only for a single-family dwelling. In addition, the graywater system must have a holding tank for graywater that is watertight and formed of solid, durable materials. The piping for a system that uses graywater for sub-surface irrigation, which discharges into the holding tank or is directly connected to the building sewer, must be downstream of any vented trap to protect the building from possible sewer gases.

US - Massachusetts

In 2002, the State of Massachusetts enacted a comprehensive wastewater reuse and graywater management plan (Government of Massachusetts, Chapter 176 of the Acts of 2002, <http://www.state.ma.us/legis/laws/seslaw02/sl020176.htm>). Graywater is similarly defined as in other states, but also may include cleaning water from public and commercial facilities and buildings. Graywater does not include wastewater discharged from toilets, urinals and drains equipped with garbage grinders, although kitchen sink and dishwasher water is not prohibited. Regulations and guidelines are due to be issued in June 2003.

US - Connecticut

A pilot program initiated in 2001 to study the effects of graywater is under way and may lead to regulations or guidelines allowing the reuse of graywater in this state.

US - Washington State

Washington State also issues permits and guidelines for the use of graywater for subsurface irrigation (drain-field or drip irrigation) of ornamental plants, provided certain design requirements are fulfilled (Washington State, Department of Health, Wastewater Management Section, <http://www.doh.wa.gov/ehp/ts/waste.htm>).

Australia

The use of treated 'blackwater' effluent from centralized wastewater treatment plants is gaining popularity in Australia. However nationwide regulations state that all domestic wastewater - fecal matters, urine, household slops, liquid wastes from sinks, baths, and all similar fixtures - (Queensland Sewerage and Water Supply Act 1949 -1982) must be disposed of into the sewer system, if there is one. Graywater reuse therefore is permitted only in non-sewered areas, where it is regulated by state and local government health acts. In the Australian state of Queensland, the installation of any graywater system, including those intended for toilet and urinal flushing, must first be authorized by the regulatory authorities. However, Queensland sewage and water supply legislation is currently under review. Victoria and other states also are investigating their graywater options. National guidelines for the use of reclaimed water in Australia and New Zealand recently have been published but are focused on disposal of the wastewater rather than reuse, and do not refer explicitly to treatment or application of graywater (AS/NZS 1547-2000, On Site Domestic Wastewater Management, 2000).

Cyprus

As already noted, the Government of Cyprus is promoting the use of graywater, in individual houses, hotels, swimming pools, and football grounds. In Cyprus, 'graywater' includes water from baths, showers, hand or washbasins and washing machines, but does not include water from toilets and kitchens.

UK

Graywater reuse is not widespread in the UK, and specific legislation regulating the use of graywater does not exist. The key regulatory requirement is compliance with the Water Supply (Water Fittings) Regulations 1999 (HMSO 1999 Water Supply (Water Fittings) Regulations 1999. Statutory Instruments No. 1148, No. 1506, Water Industry, England and Wales), which requires that mains water and other water supplied is protected against back-flow and cross-connection, and that non-mains water pipes are easily distinguished. The regulations also are applicable to certain aspects of graywater use, since any overflow from the graywater storage unit must discharge in either a foul or combined sewer. The Water Regulation Advisory Scheme (WRAS) has published information and guidance on reclaimed water systems, some of which is relevant to graywater systems (Water Regulation Advisory Scheme 1999a & 1999b). However, all of this documentation is geared towards reuse for toilet flushing rather than landscape irrigation.

3.0 Issues about Graywater Reuse

3.1 Graywater Quality

The quality of graywater varies depending on the source of the water, and the uses to which the water has been put. The following table indicates the likely constituents of water from various household sources.

Graywater Source	Possible Contents
Automatic Clothes Washer	suspended solids (dirt, lint), organic material, oil and grease, sodium, nitrates and phosphates (from detergent), increased salinity and pH, bleach, heat
Automatic Dishwasher	organic material and suspended solids (from food), bacteria, increased pH and salinity, fat, oil and grease, detergent material, heat
Bathtub and Shower	bacteria, hair, organic material and suspended solids (skin, particles, lint), oil and grease, soap and detergent residue, heat
Sinks, including Kitchen	bacteria, organic matter and suspended solids (food particles), fat, oil and grease, soap and detergent residue, heat
Swimming Pool	chlorine, organic material, suspended solids

Table 3.1: Common constituents of graywater

Various studies into graywater quality in different countries have been published. The following table gives an overview of some of the parameter concentrations, together with some guideline parameters taken from a number of sources.

Reference	BOD5 (mg/l)	SS (mg/l)	pH	EC μ S/cm	FCC CFU/100 ml
(Jeppesen 1996) □ Brisbane GW	90-120	45-330	6.6-8.7	325-1140	
(Christova – Boal et al. 1995) □ Bathroom GW	45-330	43-380	6.4-8.1	82-250	
□ Laundry GW	10-520	26-400	6.3-9.5	83-880	
(Water CASA 2000) □ Arizona GW					20- 7,640,000
(Jeppesen 1996) Guidelines for Irrigation of Plants	NA	NA	5.0-8.0	0-5000	NA

Table 3.2: Graywater quality characteristics

BOD5: biochemical oxygen demand – a measure of the amount of organic matter. It specifically measures the amount of dissolved oxygen that microorganisms use in a water sample to break down organic material at 20 degrees Celsius over a 5-day period. Clean waters have BOD5 values < 1mg/l and rivers are considered polluted if the BOD5 is > 5 mg/l (Kiely 1997). Acceptable BOD5 values range according to country and intended use. For example, Jordanian standards (JS 893) allow BOD5 values of < 150 mg/l for the irrigation of fruit and forestry trees and crops.

SS: suspended solids – measure of the amount of solid matter

PH: a measure of acidity or alkalinity (less than 7 is acidic, greater than 7 is alkaline)

EC: electrical conductivity - a measure of all dissolved salts in the water, and therefore a measure of salinity hazard. The higher the concentration of salts and minerals, the greater the potential for adverse impacts on the soil and plants. A standard classification of soils related to salinity is as follows:

Class Specific Conductivity (micromhos/cm (μ S/cm)):

0. Non saline, 0 - 2,000
1. Very slightly saline, 2,000 - 4,000
2. Slightly saline, 4,000 - 8000
3. Moderately saline, 8,000 - 16,000
4. Strongly saline > 16,000

If the EC in water increases on a frequent basis, and for a prolonged period of time, certain sensitive plants could suffer salt injury (Bennett et al. 2002).

FCC: fecal coliform count – a measure of the degree of bacterial contamination from humans and animals. Certain standards allow < 1000 CFU (colony forming units)/100 ml in the water used for crop and tree irrigation (Leggett et al. 2001a).

3.2 Effects on Plants

Most graywater is used to irrigate plants, so the most immediate risks of pollutant constituents in the graywater are related to plant health. It is assumed that users will avoid the disposal of inappropriate substances (paints, antifreeze, solvents, mothballs, wastewater from oily rags, chemicals from photo-labs, etc) into the graywater. However, many graywater sources themselves will contain substances which may have harmful effects.

Laundry products in particular use a variety of chemicals that can be harmful to plants. Most soaps and detergents - including baking soda - contain sodium compounds. High levels of sodium can cause discoloration and burning of leaves, and can contribute toward an alkaline soil condition. In addition, high sodium can be toxic to certain plants and can prevent calcium from reaching the plants (the UN Food and Agriculture Organization (UNFAO) indicates “no problems” at sodium levels of < 69 mg/l, “increasing problems” at levels of 69 – 207 mg/l, and “severe problems” at levels of > 207 mg/l) (Bennett et al. 2002). A second possible effect of some types of sodium is a disturbance of the soil’s ability to absorb water. The sodium adsorption ratio (SAR) is the parameter that measures the effect on the soil structure of sodium compounds. A high SAR (13 or above) will result in soils with reduced permeability and aeration, and a general degradation of the soil’s structure. A buildup of sodium over time therefore will reduce the soil’s ability to support plants. This is probably one of the most serious potential long-term consequences of irrigation with graywater. Reduction in the amount and concentration of sodium in the graywater – either by reducing the amount of detergents and soaps used or by using reduced-sodium products (to be discussed further later) will reduce the risk to plant health and soils. Also, flushing of the soil by freshwater or rainwater from time to time will reduce the build up of sodium in the soil. Water softeners also introduce sodium-based compounds into the water, and should be avoided where graywater is to be reused.

Detergent and laundry products also contain other chemicals that are harmful to plants such as boron, chlorides, peroxides, and petroleum distillates. Boron, for example, is very toxic to most plants. Plant damage from excess boron first shows up as “burning” of leaf edges. Other symptoms of boron toxicity include leaf tip and margin burns, leaf cupping, chlorosis, branch dieback, premature leaf drop, and reduced growth (UNFAO indicates “no problems” at boron levels of < 0.75 mg/l, “increasing problems” at levels between 0.75 and 2.0 mg/l, and “severe problems” at levels > 2.0 mg/l) (Bennett et al. 2002). On the other hand, most hand and dish soaps and shampoos used in normal residential concentrations will not damage plants (Ludwig 1995-1999). In general, gentle soaps, such as soap flakes, are more suitable than those heavily laden with lanolin, perfumes, and other chemicals. Soaps are less harmful than detergents. However, the use of any soap or detergent product may present problems over periods of sustained graywater application. If salt buildup in the landscape is a concern, it is better to use liquid detergents than powdered detergents. Powdered detergents contain excessive amounts of sodium compounds, which is often used as a ‘filler’ ingredient not essential to clothes cleaning. Many detergents also contain phosphate compounds, but these are a nutrient to plant growth, and will generally benefit the plants.

Bleaches commonly contain chlorides, which can damage plants, particularly if the bleach water actually touches the foliage. One symptom of chlorine-induced damage is a tendency for new, expanding leaves to appear bleached (UNFAO indicates “no problems” at chloride levels of < 142 mg/l, “increasing problems” at levels between 142 and 355 mg/l, and “severe problems” at levels > 355 mg/l) (Bennett et al. 2002). Bleaches carry large amounts of chlorine. Therefore, ammonia is often used as a substitute for bleach, as it also cuts grease and is preferable as a household cleaning and deodorizing agent. Ammonia itself may cause damage to plants, although it quickly oxidizes to nitrates and nitrites - themselves plant nutrients - in certain soil conditions. Although kitchen sink water is often prohibited for reuse, few of the constituents of kitchen water cause problems for plants. Organic material and bacteria are generally broken down in the soil, and do not harm plants.

3.3 Keeping the Plants Healthy

Plants irrigated with graywater should be monitored regularly for symptoms of damage. If any signs of plant injury appear, use of graywater should be discontinued or reduced. ‘Burning’ of leaf edges may be caused by excess salts in the water. Acid-loving plants may experience some chlorosis or yellowing of the foliage, due to the alkaline nature of the graywater.

If plants appear to be injured, the surrounding area should be flushed with fresh water. If possible, application of graywater should be rotated with fresh water for susceptible lawns and fruit trees. In addition, graywater should be applied over a broad area to avoid build up of harmful ingredients in one particular location. Applying graywater to the same plants all the time should be avoided. Particular care should be taken with water containing detergents, bleach or boron, and the use of rinse water containing fabric softeners should be avoided whenever possible.

Graywater can be used for ornamental trees and shrubs. However, applying the water directly to foliage or stems should be avoided, as most of the feeder roots responsible for absorbing water are located at the base of the plant. Graywater poured directly on the base of trees and shrubs could encourage crown rot. It is best to distribute the water over the whole root system, where it will be most efficiently used.

Graywater should only be used on well-established plants, not on seedlings or young plants as they are more sensitive to the impurities in the graywater. Graywater generally should not be used on potted plants because of possible build up of contaminants in the soil that can damage the restricted root systems in a confined volume of soil. In addition, graywater should

never be applied to root crops or leafy vegetables that will be eaten raw, such as carrots, lettuce, or herbs, and it should not come in contact with the edible portion of fruits and vegetables (for instance, with root vegetables, such as radishes, potatoes, and beets). Use of graywater with fruit trees, and other plants where the edible portion is well away from the water, is permissible.

If graywater is used for irrigating food plants, its application should be restricted to the soil surface around plants of which only the above ground part is eaten. Graywater should not be poured directly on plant leaves. Sprinklers should not be used in order to avoid contacting the above-ground portion of the plants. Surface irrigation should not be used for food plants, except for fruit trees. Graywater should be cool before being used since hot water can damage plant roots and stems.

Soil pH (acidity or alkalinity) is very important because it influences several soil properties that directly affect plant growth, and also has a bearing on soil bacteria and nutrient availability. Plants have a range of tolerance to pH, but most plants grow best in soils with a pH between 5 and 7. Plant nutrients generally are most available in the pH range of 5.5 to 6.5, which is also a good range for beneficial soil bacteria. When the soil pH is 5 or below (i.e. strongly acidic), nitrates, phosphates and potassium become less available to plants, earthworms disappear and bacteria become less active. Particularly alkaline soils also lock up vital mineral nutrients needed for plant growth. When the pH is 8 or higher (i.e. moderately or strongly alkaline), iron and zinc become less available to plants. Chlorotic leaves develop, and salt burn from sodium and boron tend to occur. Certain plants will be particularly susceptible to damage from graywater, particularly acid-loving plants. [Appendix I](#) contains a list of plants that are recommended for irrigation by household graywater and another list for acid-loving plants that should not be irrigated by graywater.

3.4 Effects on Soils

The main effects of graywater on soils are:

- A tendency to raise soil alkalinity and salinity;
- A reduction in the ability of soil to absorb and retain water.

Increases in alkalinity will arise due to the presence of sodium, potassium or calcium salts in the graywater, particularly from laundry detergents. The effects on plants of variations in the pH of a soil have been discussed above. Water retention also is affected by some forms of sodium – an effect measured by a parameter known as the sodium adsorption ratio – SAR. A sandy, well-drained soil will be less affected by graywater application than a poorly drained clay soil.

Guidance for quantities of graywater use is given in several publications. For example, it is stated that a well-drained square meter of loamy garden soil, rich in organic matter, is capable of handling 200 liters of household graywater each week. Sandy, lighter soils can absorb more water, and heavier soils with a high clay content absorb less (Greenhouse People's Environmental Centre).

If a soil has been irrigated with graywater for an extended period, sodium levels may build up, resulting in poor drainage and potential damage to plants. High levels of sodium may be detected by conducting a pH test of the soil. A pH of 7.5 or above may suggest that the soil has become overloaded with sodium. The Greenhouse People's Environmental Centre recommends the application of gypsum (calcium sulfate) to the soil in order to reduce the pH levels. A rate of 100g per square meter each month is suggested, until the pH of the soil drops to 7. (see <http://www.awgypsum.com/gypsum.htm>).

Fortunately, dilution of graywater by rainfall or fresh water irrigation helps flush the soil of sodium, excess salts, and other soil contaminants that might be building up. In places such as Arizona, there are two rainfall seasons that, despite the arid conditions, allow for leaching of these substances from the soil. The application of thick compost mulches is recommended by some sources to help speed up the natural decomposition of waste residues, although this will have little effect on inorganic salts.

3.5 Effects on Human Health

Contrary to popular belief, undisinfected graywater is not as hazardous to health as is sometimes thought. The main risks arise from physical contact with the graywater, and from eating fruit or vegetables that have been irrigated with the graywater. Some graywater may contain concentrations of human excretions that can be a mode of transmission of infectious disease. Infection theoretically could occur after contact with the eyes and nostrils, inhalation of mist from spray irrigation, or ingestion through crops contaminated by spray or surface irrigation. However, there are no recorded incidents of serious effects to human health from the reuse of graywater.

Human exposure to graywater is also much less an issue than is commonly thought. Firstly, since all domestic graywater was initially produced by humans, most of it already has come into contact with humans anyway – for example in the shower, or wash basin. However, it may contain pathogens and contaminants that could be a risk to human health. There may be particular risks to those from outside the family household where the graywater was produced. There are two ways to minimize this risk – one is by extensively treating the graywater to remove bacteria and other pathogens. This is how the quality of treated wastewater (blackwater) is increased to allow it to be used for unrestricted purposes. However, this is unduly expensive for householders. The second way of minimizing risk is simply to eliminate

contact between the householders and the graywater. For this reason, most sources recommend a graywater collection and distribution system that does not require regular user intervention. Also, irrigation by sprinkler is prohibited, to avoid the danger of airborne graywater coming into contact with people. Some jurisdictions even prohibit surface irrigation, although others do allow it provided quantities are controlled, and soils saturation does not occur. Irrigation of lawns and other areas where children or animals may play, other than sub-surface drip irrigation generally is discouraged, also to reduce the chance of contact. In addition, graywater should not be used to wash down patios, walkways, or driveways. It should also not be used for dust control, cooling, spray irrigation or any other use that would result in air-borne droplets or mist.

Most authorities emphasize that the introduction into the graywater of pathogens from the washing of heavily soiled laundry and diapers, or of clothes with blood or vomit should be avoided, and that where there is a particularly infectious illness in the household (e.g. diarrhea, hepatitis, measles or intestinal parasites), the graywater should be disposed of through the blackwater sewerage system and not reused.

Also, large graywater storage containers may pose a safety hazard to children. Therefore, storage containers must be tightly covered to prevent easy access, and to keep away mosquitoes, other insects, and small rodents.

3.6 Effects on the Environment

The overriding positive environmental impact of graywater reuse is the reduction in demand for fresh water. Many sources argue against the production of high quality potable water for purposes that do not require such high quality water – e.g. irrigation of plants. By reusing graywater, a reduction in demand for expensive-to-treat potable water results.

One of the main environmental risks from graywater reuse is that of groundwater pollution. Depending on the geology of the area in question, it is possible that some of the substances found in graywater could find their way into the groundwater reserves underlying the area of reuse. If the groundwater were to contain substances that would pollute or otherwise have a detrimental effect on the groundwater, contamination may result. However, two factors reduce the importance of this. First of all, the overall quantities of graywater in domestic contexts are very small – most households in the west produce no more than 200-400 liters of graywater per day. Most of the water and nutrients in the graywater will be taken up by the plants themselves. Other substances in the graywater (e.g. organic matter and bacteria) will be broken down by the topsoil. Under normal circumstances, very little of the graywater in question will actually reach the groundwater.

Additionally, one of the assumptions behind the reuse of graywater is that the householders take moderate care over what enters the graywater in the first place. If large doses of poisonous chemicals were being deposited into the graywater, then not only might groundwater be at risk, but the plants also would be in danger. If the graywater is of a high enough quality for it to be suitable for plant irrigation, then it is very unlikely to be a serious threat to the groundwater.

However, some jurisdictions do take risks to groundwater into account when permitting the reuse of graywater. For example, in Arizona, graywater may only be used in locations where groundwater is greater than 1.5 m below the ground surface (Little 2001).

3.7 Irrigation

As noted earlier, many of the potential risks to human health and other possible unfavorable side-effects of graywater reuse (for example odors, encouraging breeding of mosquitos, etc) are reduced or eliminated by prohibiting the use of sprinkler irrigation, and by the avoidance of

surface pooling of the graywater. Different jurisdictions regulate this in different ways, but generally specify irrigation to be by controlled surface flooding or by drip irrigation.

In hot climates, it is generally recommended that irrigation be carried out during the cool parts of the day (or night) to minimize water loss by evaporation. It is important that the graywater be applied no faster than the soil can absorb it, to avoid saturation and pooling of the graywater. Usually, plants are healthier when the soil is allowed to dry out between irrigations. Therefore, for best results, one should wait until the soil in the root zone is half dried out before re-irrigating.

One important potential issue in using graywater for irrigation is the danger of clogging the irrigation network from particles in the graywater. This can be eliminated by either removing solid particles from the water (by filtering or settlement) or by increasing the diameter of the holes in the irrigation pipe. It is recommended that drip irrigation hoses (with small outlets) are not used for graywater irrigation unless the solid particulates have been removed.

Some sources have reported a build up of algal growth in the irrigation pipework – the natural result of the presence of nutrients in the graywater. This does not pose a risk to either plants or humans, but should be taken into account in the design of the system. Algae may be removed by periodic chlorination of the graywater, although care should be taken in such circumstances to avoid harm to the plants.

3.8 Guidelines

Based on this preceding information, a short set of guidelines has been prepared to provide advice on graywater reuse in Jordan. Many of the important recommendations noted in the preceding discussion have been included in these guidelines, which are available in [Appendix II](#) and will be further revised following field trials and assessments being conducted in Jordan.

4.0 Graywater Reuse in Jordan

The purpose of the CSBE project is to develop graywater solutions that are relevant to Jordan. This area of the world historically has been aware of the need to conserve water and there are many past examples of water-conserving practices in Jordan. However, the direct import of solutions and ideas from other countries, even if they are suitable elsewhere, may not necessarily be appropriate to Jordan. A subsequent project report will discuss graywater in Jordan more fully. However, this chapter provides some information about graywater reuse in Jordan, past and present, and some of the issues which need to be considered.

4.1 Historical Water Conservation Practices in Jordan

The idea of water conservation is not new to Jordan. Having had to survive in an area of low rainfall, the peoples who inhabited these lands through the centuries have always been careful to minimize their water usage. Historically, harvesting of rainwater was used to provide water that is suitable for various domestic and irrigation uses. A number of distinctive historical examples that incorporate effective water harvesting systems survive in the country. These include the cut-stone reservoirs of the Nabatean city of Petra, as well as the underground cisterns found in the country's seventh and eighth century Umayyad desert palaces, the Crusader period castles such as those in Ajlun, Karak, and Shawbak, and traditional village houses of the nineteenth and early twentieth centuries. There is also anecdotal evidence of more recent unregulated domestic graywater reuse whereby wash water was saved and used manually for plant irrigation. A 1999 report by the Center for Development Research estimated that 60 % of households in Amman and 30% in rural Jordan reused water within the household (Iskandarani 1999).

4.2 Current Uses of Graywater in Jordan

Regarding the contemporary reuse of graywater, there are many examples throughout the Kingdom of people and institutions reusing their own graywater.

One of the simplest examples is at a children's playground in Shmeisani, where the spillage water from a drinking fountain unit is captured and taken to irrigate a single shrub adjacent to it. Since the water is very clean, and there is no human contact involved with the graywater, the system is basic yet effective. There is no need for filtering or treatment of any kind, and there are no adverse effects on the plant.

Three other simple examples, this time in rural households, are worth noting. One householder in the north of Jordan has diverted the outlet of his only sink into a shallow reservoir in his yard – Figure 4.1. The graywater is stored in the reservoir from which it is manually applied to olive trees via a bucket. There is no treatment. The water is mostly the output from dish washing and clothes washing. The open nature of the storage pool is a potential attraction to vectors but is apparently not a sufficient disincentive to this particular householder.



**Figure 4.1: Graywater storage in Adasiyyah
(Photograph by CSBE)**

Another house, in the same village has no internal plumbing. All washing is carried out at the row of faucets adjacent to the water tank – shown in Figure 4.2. The wash water drains directly to a row of banana plants and olive trees. It is worth noting that this householder has noticed a stress reaction from the banana trees to laundry water. Wash from laundry water has been therefore diverted only to the olive trees, whose tolerance to the contents of this wash water appears to be higher.



**Figure 4.2: Graywater reuse in Adasiyyah
(Photograph by CSBE)**

This house in a nearby village is also worth a mention. With no indoor plumbing, this house has only one water tap, which provides water for all drinking and washing activities. Figure 4.3 shows the plants in the yard that are irrigated by drainage from this single tap. The graywater runs naturally towards the plant roots. Not only is there no storage or treatment, but in this

case there is no plumbing. All the plantage shown is irrigated solely from the graywater, together with whatever occasional rainfall there is.



**Figure 4.3: Graywater-irrigated yard foliage
(Photograph by CSBE)**

At the King Abdullah Mosque, wastewater from the ablutions of worshippers is collected, pumped to a rooftop storage system – Figure 4.4 - where it is filtered and reused to irrigate some fairly extensive areas of ornamental plants in the grounds of the mosque. The system was installed around 5 years ago, and has resulted in a significant saving on the mosque's water bills. In fact, the capital costs for the installation of the system were recouped within the first year of operation. Since the water used for ablutions is of a relatively high quality to begin with (it has very little soap content), there are no adverse effects whatsoever on the plants.



**Figure 4.4 King Abdullah Mosque
(Photograph by CSBE)**

Care International, in conjunction with a number of Jordanian organizations, in particular the Inter-Islamic Network on Water Resources Development and Management (INWRDAM) has distributed a number of graywater kits and provided training to villages in rural Jordan in a program initiated in 1990. INWRDAM also has been influential in developing a low-sodium shampoo and detergent for use in areas where graywater is being reused (see [Appendix II](#), note *).

A number of private householders have also installed graywater system of various kinds. One good example is the HB house in Amman, where graywater from one bathroom in the house has been intercepted at an external manhole and is taken to a horizontal 2" PVC underground pipe with holes arranged at intervals, supplying the water to a row of plants – Figure 4.5. There is no pumping or filtering of any kind. No change of behavior was necessary on the part of the householders, since all the water from the bath, shower, and bathroom sink is applied directly and automatically onto the plants. This system has been operating for over 2 years and there are no signs of stress on the plants or the soil. The cost of the manhole divert and the piping are reckoned to be of the order of 20JD (about 28 \$US), and there is little or no ongoing maintenance required.



Figure 4.5: Plants irrigated with bathroom graywater – no filtering or treatment (Photograph by CSBE)

A second, very different system has been observed at NF house, also in Amman. This recently built house was dual-plumbed during its construction, and a dedicated underground collection tank and treatment system was installed. Graywater was collected from a number of bathrooms and sinks, excluding the kitchen sink, but including the washing machine. The collected graywater was filtered and pumped through a sprinkling irrigation system. However, this system, although designed and installed as an integral part of the house, was abandoned within the first two months of operation due to adverse odors from the irrigation water. Analysis of the system revealed certain inadequacies such as inappropriate application via a sprinkling system. By making some minor adaptations to this system, it would be possible to have it working successfully.

4.3 Relevant Issues Particular to Jordan

There are a number of issues particular to Jordan that may affect how graywater reuse is implemented in the kingdom.

Plumbing

The vast majority of houses in Jordan are constructed of reinforced concrete. Water and wastewater pipes generally are cast into the floor slabs. Access to the pipes is therefore difficult, disruptive and costly. In addition, plumbing practices are not consistent and do not

always conform to the standards required by the regulations. According to Jordanian regulations (see below), graywater from bathrooms should be kept separate from the toilet water until the manhole outside the house. This should make the interception and use of graywater relatively easy. However, this practice generally is not followed. The disturbance factor and cost of retrofitting a concrete house, unless it is undergoing a major refurbishment, makes the economics of graywater use unfavorable in these cases since the costs saved are unlikely to pay for the plumbing and installation. It is vastly preferable therefore for new houses to be dual plumbed (i.e. plumbed with a separate plumbing line for graywater) from the beginning.

However, where new houses are concerned, or where the plumbing is either separate or accessible, labor costs are low, and parts are cheap and easily available.

Limited Water Supply & Conservative Practices

As noted earlier, the per capita water usage in Jordan is significantly below that of developed countries, as illustrated in the following table.

	Avg Per Capita Water Use (liters/person/day)
Jordan	126 average (Hashemite Kingdom of Jordan 2002) 60-70 low income (Center for Development Research 1999)
US	300 (projected for 2000) (World Bank 2001)
Europe	225 (average) (Kiely 1998)
Cyprus	110-150 (residents) 390 (tourists) (Kambanellas 1999)

Table 4.1: Per capita water usage

The overall potential for graywater reuse is therefore already more limited than in other countries. There simply isn't as much graywater around to begin with. This leads out of necessity to conserving practices that are not often observed in countries where water is more plentiful. This is especially the case for moderate to low income families whose household water is supplied from a 1 – 2m³ storage tank which must serve the household for 4 – 5, sometimes 6 days of the week, (since the municipal water supply only operates for a limited time each week). Conservation is a must to avoid running out of water before the supply is restored. For example, few Jordanians will allow taps to run when washing either food or persons. Lower income families do not generally have bathtubs in their homes, and even showers tend to be rationed and curtailed where there is an awareness of the limited water supply. This undoubtedly leads to more concentrated graywater effluent, although insufficient water quality data for Jordan has been found to support this. The limited water supply is therefore one of the best sources of encouragement to water conservation, particularly for moderate to low income families, but it may preclude against the economically feasible reuse of graywater.

The Intermittent Nature of the Water Supply

The intermittent nature of the water supply already has been discussed. All municipal areas receive pumped water from the water authority for a limited number of days each week, varying (reportedly) from 1 to 4 days per week, depending on location and time of year. Each household stores the municipal water in tanks, either on the roof of the property or underground. Most low-income households have storage capacity of 1 m³ or 2 m³, which must be conserved so that it will last the 4 – 6 days until the municipal supply is restored. Because

of this, most high water usage (e.g. floor washing and laundry) is confined to or at least occurs mostly during ‘water days’. Consequently, the production of graywater is low during no-water-supply days, peaking significantly during water-supply days. This uneven production of graywater will have an effect on how graywater is stored and used. Ideally, the use of graywater for irrigation should be fairly evenly dispersed throughout the week. In an extreme case, a household that effectively produces all its graywater during the one day when the water supply is on will need to store this graywater in order to provide a balanced delivery of water for irrigation. The higher cost of providing this storage, in comparison to a household that only needs to store graywater for 3 days, may be significant.

The Low Cost of Water

The real costs of water supply and distribution in Jordan are not passed on to the domestic consumer – particularly the low-end consumers. This provides a disincentive to conserve for the low to medium income user. Current domestic water tariffs increase with usage, and those for Amman are summarized in the table below.

Quarterly Usage (m ³) Domestic	Cost JD/m ³
0-20	Fixed bill value 2.972
21-40	0.159
41-70	0.479
71-100	0.772
101-120	0.968
> 121	1.242
Non-Domestic Use – Municipal Supply	1.650
Private Vendor	1.000 – 4.000 (varies) (Center for Development Research 1999)

Table 4.2: Current water prices in Amman

These low prices reduce the effective ‘financial savings’ to be made by reusing graywater, particularly by low-end consumers.

Variation in Income

The large economic disparity between high income and low income households in Jordan affects the ability to purchase water, with high income users being able to afford large underground tanks in which to store municipal water, and also to supplement municipal water supplies through purchase of water from privately operated water trucks. Lower income households cannot afford these methods and must make do with the limited available water supply.

These differences are expressed in per capita water use. The moderately affluent families of Amman have lifestyles comparable to Europe and the US (having baths, western toilets, irrigated gardens, cars in need of washing, etc) with corresponding per capita water use of 300 – 400 liters/person/day, while people in rural areas (having neither the same water use requirements, nor the means of storage and supply) make do with perhaps as little as 60-70 liters/person/day (Iskandarani 1999).

4.4 Current Legislation in Jordan Regarding Graywater Reuse

The Plumbing Codes

The Jordanian regulations governing household plumbing are the 'Sanitary Wastewater System Code', and the 'Water Supply Code' (Ministry of Public Works and Housing 1988). These codes provide guidelines for the design and installation of plumbing systems in domestic properties. The Water Supply Code provides guidelines for the supply of hot and cold water to buildings including fire fighting systems. This code has little or no relevance to graywater reuse and plumbing.

The Sanitary Wastewater System Code provides guidelines for internal and external drainage and wastewater systems, and gives recommendations for pipe types and dimensions and for design of rainwater gutters. It provides extensive design guidelines for septic tanks. The codes suggest (2/4/2, page 20) that all wastewater should be discharged using a sanitary wastewater system in accordance with the recommendations laid down in the code, and prohibits wastewater discharge according to any other method. There is no explicit prohibition of the installation of a separate plumbing system for graywater. On the contrary, it is recommended that the toilet, bidet and urinals should not be connected into the same pipe as the floor drains and sinks, until outside the building. A suggested layout (page 85) for a domestic wastewater system shows the wastewater from the toilet and bidet being kept separate from the shower and sink until outside the building where they are connected at a manhole.

The code requires that each pipe joint, bend or change in level outside the property is facilitated by an access chamber (manhole). The code also suggests (page 85) that each bathroom has its own external manhole, and requires (page 62) wastewater to be discharged into the municipal drain where possible, and failing this, to a septic tank.

Although graywater reuse is not expressly permitted, many of the above requirements – if implemented – could facilitate the use of graywater. A governmental committee recently has been formed to examine the codes in light of the potential for graywater reuse, and to propose amendments that would allow the reuse of graywater more easily, in particular to require all household plumbing to separate graywater from blackwater until outside the building.

Jordan Standard 893, Reuse of Wastewater for Irrigation

This standard regulates the quality of treated wastewater that may be used in irrigation in Jordan. The code generally is applied to the reuse of treated wastewater – blackwater - from municipal wastewater treatment plants. It is arguable that the guidelines given in this code may not be relevant to the small-scale use of graywater in a domestic context, given the vast difference in the quantities involved. The parameter levels set in the code are for the protection of the health of both agricultural workers and consumers of the irrigated produce, and also for the mitigation of impacts on the environment, in particular degradation of the surface water and groundwater resource, due to the large-scale use of treated wastewater.

4.5 Economic Factors

The Individual Consumer

There are two aspects to the economic picture in relation to graywater reuse. The simpler one concerns the individual household consumer. A domestic consumer has a particular annual water requirement. For the water supplied to him, either by the Water Authority of Jordan (WAJ) or a private supplier, he pays a charge. This charge is dependent on the water use – the tariffs were presented in Table 4.2.

If a component of the supplied water can be reused, a reduction in the amount of water purchased by the household will result, and a financial saving may follow. However, a capital cost is associated with the introduction of a graywater reuse system (for example additional pipes, treatment, etc), there will be a period of time before this capital cost is 'paid for' through savings in water bills. The amount of time this takes will depend on the initial cost of the system, the amount of water saved by reusing the graywater, and the water tariff. For households in the lowest tariff, there will be no direct monetary saving as a result of lower water usage. For large user households, particularly those with a large irrigation demand, the savings may be significant enough to make the cost of installing a graywater system worthwhile in the medium term on purely economic grounds.

For households whose water income is limited not by earnings but by supply constraints (i.e. who use all the water they can get, and who could pay for more water if they could get it), the result will not be a financial saving, but a release of an amount of additionally available water for their household use. This may prove to be a more motivating factor than a straight saving in water bills. Such a household may be able to put off the expense and effort of installing (for example) an additional storage tank by reusing their graywater.

The Big Picture

However, it is upon looking at the bigger picture that the potential advantages become more significant. Jordan's annual water supply deficit was outlined in Chapter 1. Even investment in additional collection, storage and distribution infrastructure will not eliminate the gap in Jordan's water needs. Restructuring the water sector institutions may help increase the efficiency of distribution and cost recovery, but will not actually provide more water. Management and reduction of the growing demand must play its part.

It has not yet been established that graywater reuse on a large scale will be feasible or achievable in Jordan. There are technical and other issues that need further investigation before graywater reuse can be widely promoted. Also, the direct financial incentives to the low-use domestic consumer are minimal. However, other countries have demonstrated a significant overall reduction in domestic demand as a result of graywater reuse, and there is no reason to assume that significant demand reduction is not achievable in Jordan. The cost of producing this demand reduction is difficult to estimate – clearly in such a decentralized solution, there is an inefficiency or duplication in infrastructure. However, depending on how graywater reuse is implemented and funded, there may be significant hidden savings arising from the mobilization of a hidden resource of householders who would implement and maintain their systems at no cost to the Water Authority. Large-user households will see a reduction in water bills – a saving which will increase as the real costs of water are passed on to the consumer in the form of increased tariffs. Low-user households also will benefit, less in the direct financial saving, and more in the increase in the amount of water available to them, at minimal cost. The Water Authority of Jordan is best placed to put a monetary figure on what this demand reduction saving is worth, but it may be significant.

5.0 Conclusion

Graywater reuse is an increasingly common household practice in a number of arid countries, and, in some areas, is practiced whether legal or not. A range of technical solutions are available, and there are simple ways to minimize the adverse impacts on plant and human health. An increasing number of authorities are beginning to permit and regulate graywater reuse.

There is every reason for householders in Jordan, with its increasing annual water deficit, to examine how best graywater reuse can be implemented in their homes. This report has presented ways in which graywater is reused in other countries. This CSBE study will go on to study the practical reuse of graywater in Jordan and will develop and publish advice and guidance on how best to reuse graywater for garden irrigation safely and economically.

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Appendix I:

I.A: Selected List of Plants that Tolerate Alkaline Soils
(Plants that tolerate irrigation by graywater)

Botanical Name	English Common Name	Arabic Common Name	Group
<i>Acacia cyanophylla</i>	Mimosa	أكاشيا	Evergreen tree
<i>Acacia farnesiana</i>	Sweet Acacia	عنبر	Deciduous tree
<i>Acacia greggii</i>	Catclaw Acacia	—	Deciduous tree
<i>Agave palmeri</i>	Foxtail Agave	أجاف	Succulent
<i>Albizia julibrissin</i>	Silk Tree	ألبيزيا	Deciduous tree
<i>Aloe nobilis</i>	Golden-tooth Aloe	ألوي	Succulent
<i>Bougainvillea sp.</i>	Bougainvillea	مجنونه	Evergreen vine
<i>Brachychiton populneus</i>	Bottle Tree	بدة العفريت	Evergreen tree
<i>Buddleia davidii</i>	Butterfly Bush	طرف العروس	Deciduous shrub
<i>Caesalpinia gilliesii</i>	Bird of Paradise Bush	شوارب النمر	Deciduous shrub
<i>Ceratonia siliqua</i>	Carob	خروب	Evergreen tree
<i>Cereus peruvianus</i>	Apple Cactus	صبر	Cactus
<i>Chamaerops humilis</i>	European Fan Palm	شميروبس	Evergreen tree
<i>Cortaderia selloana</i>	Pampas Grass	حلفا	Ornamental grass
<i>Cupressus arizonica</i>	Smooth Arizona Cypress	سرو فضي	Evergreen tree
<i>Cupressus sempervirens</i>	Italian Cypress	سرو عمودي	Evergreen tree
<i>Dodonaea viscosa</i>	Purple Hop Bush	دودينيا حمراء	Evergreen shrub
<i>Eucalyptus camaldulensis</i>	Red River Gum	كينا	Evergreen tree
<i>Grevillea robusta</i>	Silk Oak	جرا فيليا	Evergreen tree
<i>Iris sp.</i>	Bearded Iris	سوسن الصحراء	Evergreen perennial
<i>Lantana camara</i>	Lantana	أم كلثوم	Semi evergreen shrub
<i>Lantana montevidensis</i>	Trailing Lantana	أم كلثوم زاحفة	Perennial
<i>Laurus nobilis</i>	Sweet Bay	غار	Evergreen tree
<i>Lavandula angustifolia</i>	Lavender	لافندر	Evergreen shrub
<i>Lonicera japonica</i>	Japanese Honeysuckle	ياسمين عراقي	Evergreen vine
<i>Malephora crocea</i>	Ice Plant	—	Succulent
<i>Morus</i>	Mulberry	توت	Deciduous tree
<i>Myrtus communis</i>	Myrtle	ريحان، أس	Evergreen shrub
<i>Nerium oleander</i>	Oleander	مقرّمة دقلة	Evergreen shrub
<i>Nolina sp.</i>	Mexican Grass Tree	أرجيلة	Perennial
<i>Oenothera sp.</i>	Evening Primrose	—	Perennial
<i>Olea europaea</i>	Olive	زيتون	Evergreen tree
<i>Opuntia ficus-indica</i>	Prickly Pear	صبر	Cactus
<i>Parkinsonia aculeata</i>	Jerusalem Thorn	بركنسونيا	Deciduous tree
<i>Pennisetum setaceum</i>	Fountain Grass	حلفا حمراء	Ornamental grass
<i>Penstemon sp.</i>	Beard Tongue	—	Perennial
<i>Petunia hybrida</i>	Common Garden Petunia	بتونيا	Perennial
<i>Phoenix dactylifera</i>	Date Palm	نخلة	Evergreen tree
<i>Pinus halepensis</i>	Aleppo Pine	صنوبر حلبى	Evergreen tree
<i>Pistacia atlantica</i>	Betoum	بطم أطلسي	Deciduous tree
<i>Prosopis sp.</i>	Mesquite	الغاف	Deciduous tree
<i>Punica granatum</i>	Pomegranate	رمان	Deciduous tree
<i>Robinia psuedoacacia</i>	Black Locust	روبينا	Deciduous tree

<i>Rosmarinus officinalis</i>	Rosemary	حصالبان	Evergreen shrub
<i>Salvia microphylla</i>	Sage	ميرامية زينة	Evergreen shrub
<i>Senecio cineraria</i>	Dusty Miller	فضية	Evergreen shrub or perennial
<i>Sophora japonica</i>	Japanese Pagoda Tree	صوفورا	Deciduous tree
<i>Syringa vulgaris</i>	Lialac	---	Deciduous shrub
<i>Tamarix aphylla</i>	Tamarisk	إتل	Deciduous tree
<i>Tecomaria capensis</i>	Cape Honeysuckle		Evergreen shrub or vine
<i>Vitex agnus-castus</i>	Chaste Tree	كف مريم	Deciduous tree
<i>Washingtonia filifera</i>	Washingtonia	واشنطنيا	Evergreen tree
<i>Yucca aloifolia</i>	Spanish Bayonet	حرية	Evergreen shrub
<i>Ziziphus spina-christi</i>	Jujube	سدر	Deciduous tree

I.B: Selected List of Acid-Loving Plants
(Plants that do not tolerate irrigation by graywater)

Botanical Name	Common English Name	Common Arabic Name	Group	Comment
<i>Camellia japonica</i>	Camellia		Evergreen shrub	Likes acid soils with plenty of moisture
<i>Magnolia grandiflora</i>	Southern Magnolia		Evergreen tree	Gets chlorosis from alkaline soils
<i>Magnolia soulangiana</i>	Saucer Magnolia		Deciduous tree	Gets chlorosis from alkaline soils
<i>Gardenia jasminoides</i>	Cape Jasmin, Gardenia		Evergreen shrub	Requires acid soils, hard to grow in alkaline soils
<i>Rhododendron sp.</i>	_____	_____	Evergreen or deciduous shrub	Plant in raised beds in alkaline soils
<i>Azalea sp.</i>	_____	_____	Evergreen or deciduous shrub	Plant in raised beds in alkaline soils
<i>Taxus baccata</i>	English Yew	_____	Evergreen shrub or tree	Does not tolerate alkaline soils
<i>Cornus canadensis</i>	Bunchberry	_____	Deciduous carpet plant	Best in acid soils (<i>Cornus mas</i> tolerates alkaline soils)
<i>Ilex aquifolium</i>	English Holly	_____	Evergreen shrub or tree	Prefers slightly acid soils
<i>Nandina domestica</i>	Heavenly Bamboo, Sacred Bamboo	_____	Evergreen shrub	Subject to chlorosis in alkaline soils
<i>Protea sp.</i>	Protea	_____	Evergreen shrub	Most prefer acid soils (<i>Protea neriifolia</i> will grow in alkaline soil)
<i>Prunus caroliniana</i>	Carolina Laurel Cherry	_____	Evergreen shrub	Often shows salt burn and chlorosis in alkaline soils
<i>Taxodium distichum</i>	Bald Cypress	_____	Deciduous tree	Takes any soils except slightly alkaline
<i>Tsuga sp.</i>	Hemlock	_____	Coniferous evergreen tree and shrub	Grows in acid soils
<i>Wisteria sinensis</i>	Chinese Wisteria		Deciduous vine	In alkaline soils watch out for chlorosis

Appendix II: CSBE Preliminary Graywater Guidelines

CSBE - Graywater in Jordan **Preliminary Guidelines for Using Graywater for Irrigation** **(taken from <http://www.csbe.org>)**

CSBE is currently implementing a project to assess the potential of graywater reuse in domestic and small scale contexts in Jordan, and develop guidelines to ensure that graywater is used safely and appropriately. The Jordanian Ministry of Planning - Enhanced Productivity Program, is funding the project.

Graywater is the output from bathtubs, showers, sinks and washing machines, which although soiled, is not as contaminated as toilet water, and may therefore be used for irrigation of plants with little or no treatment, provided some simple safeguards are met. In the simplest system, the graywater may be able to drain directly into the irrigation system.

When reusing graywater, a number of issues need to be taken into consideration. The system should be as simple and easy to use and maintain as possible. The system should also minimize risks to human health, either by providing for adequate treatment of the graywater, or by minimizing contact between the graywater and humans (and animals). The system also should minimize the risks to plants, which may arise from some of the constituents of the graywater, particularly chemicals from soaps or detergents (such as boron, bleach, and sodium), which could adversely affect plant health.

The following are basic, preliminary guidelines for the development of graywater irrigation schemes.

Sources of Graywater

1. In order to reuse graywater from a particular building, a 'dual plumbing' system is required to separate the usable graywater from the more contaminated 'blackwater.' The outputs from toilets, bidets, and kitchen sinks are not suitable for use in irrigation without proper treatment, and should be taken to the foul sewer or the septic tank. Only wastewater from 'cleaner' sources, such as baths, showers, hand basins, and floor drains should be included in the graywater system.
2. Care should be taken to limit the release of inappropriate substances into the graywater system. Heavily soiled or bloodstained clothes, diapers, animals, etc should not be washed in sinks draining to the graywater system. Chemicals such as bleach, cleaning agents, paints, etc should not be disposed of into the graywater system, nor should any substance that may cause blockage, or detrimentally affect the plants to be irrigated with the graywater. Detergents (like those used in washing machines) have a detrimental affect on some plants because of their high sodium content. Consequently, if laundry wash water is to be used for irrigation, a degree of treatment or occasional irrigation with cleaner water may be required (this is the subject of further investigation). If possible, environmentally friendly soaps - such as those that are potassium-based - should be used in order to minimize the amount of sodium applied to the plants. *
3. When designing a system, an estimate of the size of the graywater resource should be made. How much graywater is produced in one week, and how is this distributed? A dwelling that receives municipal water for 1 day each week and has a 1m³ storage tank will produce most of its graywater during the day when the municipal water supply is on, and will produce relatively little graywater during the remaining

days. Users may wish to store the graywater to ensure a more even distribution. On the other hand, a house that receives municipal water supply for 4 days, and/or has a large underground tank, will produce graywater more evenly during the week. The graywater demand should be estimated (i.e. the amount and type of plants to be irrigated) to ensure that the demand and supply are reasonably well matched.

4. It is recommended that each household use its own graywater for its own purposes, rather than sharing graywater with other households. This avoids potential conflicts, and increases confidence over the quality of the graywater.

Treatment of Graywater

5. Relatively clean graywater needs little treatment if it is to be used simply to irrigate trees or shrubs via a sub-surface irrigation system – in other words, if the likelihood of human contact is low. Such graywater may be released directly into the irrigation network. If there is a chance of a sudden release of graywater (for example from a bath being drained, or a washing machine being emptied), then the system should be designed to handle such surges to avoid ponding on the soil surface, for example by the employment of a small surge tank.

6. Graywater that contains lint, hair, or other solid material may cause periodic clogging of the irrigation system. A simple filter may be required – for example a screen mesh in the surge or storage tank. This filter may need periodic cleaning.

7. Graywater should not be applied directly to plants if it is hot. If hot laundry wash water is to be used, means to store the graywater temporarily, in order for it to cool, should be provided.

8. Graywater may be stored, if desired. However, this may give rise to unpleasant odors. The storage tank therefore should be covered to prevent the escape of odors to areas where they would cause annoyance, but also should be vented appropriately to allow odors to escape to the atmosphere, away from areas frequented by people (for example to the roof). It should be possible to completely drain storage tanks every now and then to avoid pooling of graywater and possible contaminant buildup. If no filter is used, the outlet pipe should be located higher than the base of the tank to allow solid material to settle.

9. All pipes containing graywater should have a slight gradient to prevent graywater from lying in the pipes, and should be designed to avoid traps where graywater can lie.

10. Means of diverting the graywater to the sewer system or septic tank should be provided, in case of accidental release of harmful substances (bleach, nappy rinse, etc) into the graywater system. This will prevent contamination of the irrigation system, and damage to the plants.

11. If a potable water supply is to be included (in order to dilute or supplement the graywater supply), there should be no risk of cross-contamination between the potable water and the graywater. If a potable input pipe is included in a graywater storage tank, an air gap of minimum 300mm should be maintained between the potable water pipe and the maximum level of the graywater. A non-return valve should be provided in the potable water pipe as secondary protection to prevent accidental return flow into the potable water supply. The potable water supply could be governed by a level-sensitive valve to cut off the flow of potable water when it is not required. An overflow pipe also should be provided.

Use of Graywater

12. Graywater is best suited to the irrigation of plants, trees, and shrubs. Ideally, the area to be irrigated should be at a lower level than the graywater outputs so that the entire system can operate by gravity, and the need for a pump is avoided.
13. Drip irrigation hoses with small holes may clog due to the presence of solid material in the graywater, or following the growth of algae in the hose. Therefore, holes of at least 3mm diameter should be provided.
14. For untreated graywater, the possibility of human contact should be avoided. Graywater therefore should not be used for the irrigation of lawns, unless they are for ornamental purposes only, and are not used by children or household animals. Sub-surface irrigation also reduces the risk of human contact. However, surface irrigation is permitted provided the user is careful to avoid contact with the graywater. Irrigation by sprinkler is not permitted.
15. Irrigation of ornamental and fruit trees is permitted. Irrigation of vegetables that will be cooked before they are eaten is also permitted, provided the graywater makes no contact with the vegetable. However, irrigation of vegetables that have contact with the ground (e.g. potatoes) or that are likely to be eaten raw (e.g. lettuce, carrots, tomatoes), should be avoided, as should irrigation of herbs. Graywater is best suited for irrigate of mature plants (not saplings), which have considerable tolerance to salinity, sodium, and high pH. A list of such plants is being prepared by CSBE.

These guidelines have been developed in accordance with advice and practice in other countries. The CSBE Graywater Investigation Project eventually will provide enough information to develop guidelines that are specifically appropriate to Jordan. Although provided in good faith, these guidelines should be regarded as preliminary.

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Notes

For additional information on using graywater for irrigation, see Val Little, *Graywater Guidelines* (Tucson: Water Conservation Alliance of Southern Arizona, 2002). This document is available online through the [Water CASA](#) web site.

Also see the Oasis Design web site (www.oasisdesign.net), which has extensive information on the subject of graywater.

* The Inter-Islamic Network on Water Resources Development and Management (INWRDAM), an Amman-based autonomous intergovernmental organization, has developed and also initiated the production of environmentally friendly soaps. For information concerning these soaps, contact INWRDAM (tel. 962 6 5332993; fax. 962 6 533 2969; inwrdam@nic.net.jo; www.nic.gov.jo/inwrdam)