RESEARCH ARTICLE OPEN ACCESS

The Reuse of Greywater Recycling For High Rise Buildings in Kuwait Country

Ahmed Ibrahim Abd Alaziz & Naji Fahad Al-Saqer

Abstract
The domestic grey water recycling and reuse in high rise buildings has been discussed and detailed. It is estimated that the usable domestic grey water resource could amount from to 35% to 39% of the total domestic demand. A summary of worldwide review of recycling and reuse of grey water is reported. In many cases, light grey water from bathroom sinks, baths and showers can be directly reused in garden irrigation. Dark grey water from laundry, dishwashers and, in some instances, kitchen sinks should be subjected to simple treatment to be reused in non-potable contexts such as toilet flushing and garden irrigation. In all cases, disinfection by chlorine or ozone is important if there is a possibility contact with human exists. Therefore, there are verity of system designs from simple to sophisticated systems according to the quality and of the grey water and the type of reuse. Examples of these systems, filters and storage tanks are presented and explained. Black water from the toilet is allowed to flow directly to the septic tank or to the sewer of municipal wastewater system.

I. INTRODUCTION

Because of increasing population, and the subsequent growing demand for potable water, diminishing natural water resources, changing lifestyle patterns and urbanization, the world is on the brink of an unprecedented water crisis in the near future. The problem is getting more worth with the increasingly stringent wastewater quality discharge regulations and requirements for environmental protection. Climate change may also play a part, as well as the desire to provide more environmentally sustainable solutions for new developments. This situation creates a driving force for developing domestic water reuse especially in arid countries such as Kuwait. In this research, the greywater recycling and reuse are overviewed and discussed for high rise buildings. These include the domestic and commercial installations.

II. LITRATURE SURVEY

Definition of grey water

Greywater can broadly be defined as all wastewater generated from domestic and commercial buildings, excluding that produced from toilets and urinals. Greywater can include wastewater from bathroom sinks, baths and showers (light grey), and may also include waste from laundry facilities, dishwashers and, in some instances, kitchen sinks (dark grey). This water is not contaminated as toilet water (Black water) and can be easily treated onsite for reuse in non-potable contexts such as toilet flushing and garden irrigation. Studies in other countries have estimated that the usable domestic greywater resource could amount to 35% of the total domestic demand [1]. Clean greywater is also produced by non-domestic establishments such as swimming pools, restaurants, hotels, schools, and other public buildings.

The greywater can be collected before it goes to the septic tank or the municipal wastewater system, and may be reused to irrigate plants after providing simple treatment. With a little additional treatment, this water can be also used for toilet flushing and other applications. Of course, some safeguards are required. The risks to the human and plant health should be minimized. In certain cases, no treatment may be required.

In other countries worldwide, where water is scarce, the greywater reuse is being increasingly practiced and often occurs whether legal or not. The technical means of providing safe ways to reuse greywater, and the issues associated with health and environment have been examined in detail by a number of authorities. In this research, the methods of grey water reuse worldwide are explained, and some of the issues which may affect the transfer of such technology and practices to Kuwait are discussed.

Advantages of greywater reuse

Greywater can be used directly in gardens and, if treated appropriately, flush toilets and wash clothes. The main advantages of greywater reusing are:

- Reduce potable water consumption,
- Reduce load on the municipal wastewater system,
- Reduce the cost of pump out fees.

Disadvantages of greywater reuse

The disadvantages of greywater reuse may include:

- Additional cost of installing and maintaining the greywater system,
- Most systems require a degree of control, and maintenance,
- Risk of pollution, therefore it is important installing suitable equipment to prevent the potential health and environmental impacts [2].

Grey water Quality

The quality of greywater varies depending on its source. For example, Automatic clothes washer output contains suspended solids, organic material, oil and grease, sodium, nitrates, phosphates (from detergent) and salts. The pH of this water is high. Table (1) indicates summery of the possible constituents of greywater from automatic clothes washer and other domestic sources.

It is to be noted that heat is rejected with the most of these sources. In this case, the grey water must be settled for some time in a storage tank for cooling. The pH value of this water may be high due to the output from the automatic clothes washer and the automatic dishwasher. Therefore, care must be taken when this water is used directly in the garden. The pH value of the water should be within the accepted limits for irrigations and tubes [2].

Table (1) Typical constituents of greywater.

Greywater Source	Possible Contents
Automatic clothes washer	Suspended solids, organic material, oil and grease, sodium, nitrates, phosphates (from detergent), salts and high pH.
Automatic dishwasher	Organic material and suspended solids (from food), bacteria, fat, oil and grease, detergent material salts and high pH.
Bathtub and shower	Bacteria, hair, organic material and suspended solids, oil and grease, soap and detergent residue.
Sinks, including Kitchen	Bacteria, organic matter and suspended solids (food particles), fat, oil and grease, soap and detergent residue.
Swimming pool	Organic material and suspended solids.

Greywater Reuse in Other Countries

The greywater reuse is being increasingly practiced in a number of countries, whose water crisis is less critical than that in Kuwait. Some of these countries have carried out assessments of greywater reuse practices and investigated the technical means of reuse as well as the human health and environmental impact. The following are some examples where information on greywater reuse has been found, and is currently being practiced.

In the USA, numerous trials, studies and assessments have been carried out, and reported. Several states have developed legislation to allow greywater reuse in different circumstances. California was the first state to study and permit the reuse of greywater. Greywater was being permitted in Santa Barbara as early as the 19th Century. A pilot study into greywater reuse in the Los Angeles area was carried out in the 1980s. A Code to regulate the reuse of domestic greywater was issued in 1977. In Arizona, greywater is permitted for use in household garden irrigation. Guidelines for greywater reuse have also been prepared. A 2000 study showed that greywater reuse was common in Arizona for irrigation of ornamental trees, even before legislation and guidance were available [3].

Studies in Australia were carried out by Jeppesen and Solley [4] to assess the potential for greywater reuse. These studies concluded that significant water savings could be made from the reuse of greywater provided adequate safeguards were followed. No information regarding the degree for greywater reuse in Australia has been uncovered.
Cyprus has initiated a subsidy program for households that wish to install greywater reuse systems for domestic landscaping and toilet flushing. There is also documentation of greywater reuse at certain hotels and at least one sports facility. Dual plumbing systems have also been introduced by Kambanellas [5] at 1999 to allow the reuse of greywater in toilet flushing.

In UK, the Environment Agency, CIRIA has published studies on greywater treatment and reuse for toilet flushing CIRIA 2001 [6]. In these studies, a number of pilot plants, where greywater was captured and treated for use in toilet flushing have been described. Filtration and disinfection were employed to raise the quality of water to the desired standards. It is estimated that around 150 greywater systems

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 greywater reuse could be promoted on a more widespread basis.

Greywater 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, Japan, the greywater recycling and reuse is mandatory for buildings with an area over 30,000 square meters or high rise buildings with a potential reuse of 100 cubic meters per day as reported by Hanson [7].

Pilot studies have also been carried out by the Islamic Network for Water Resource Demand Management in Palestine and Lebanon, although greywater reuse in these countries is not thought to be widespread [8].

III. CASE STUDY

Treatment of grey water in Kuwait Country

Technical Aspects

The safe reuse of domestic greywater for irrigation is not sophisticated. Greywater is captured from the various household sources (sinks, hand-basins, showers, etc), and taken to a distribution system. In case of reuse for toilet flushing, a slightly more sophisticated treatment and storage is required. However, the components of any type of greywater system may therefore be summarized as following steps:

1- Separation and collection of Greywater.
2- Treatment procedure.
3- Storage and reuse.

The following is a discussion of the main features of greywater sources, separation, collection, treatment, storage and reuse, based on an examination of research and studies conducted in Kuwait country.

Sources of Grey water

The greywater is the normal household liquid wastes, other than toilet wastes. In most Kuwait country, the sources of domestic greywater are the same in all places . They include wastewater that flows from baths, bathroom sinks, bathroom showers and wash basins. Laundry water from washing machines is also used in many areas. This water may contain suspended solids and high concentrations of chemicals and may cause problems if it is directly reused in irrigation. Therefore, reuse of laundry water sometimes is discouraged or needs a sophisticated and expensive treatment. However, both bathroom and laundry water are generally less polluted than kitchen sink water, and so are easier to reuse.

In Kuwait country water from the kitchen sink and automatic dishwasher are prohibited from entering the greywater stream since they are high in suspended solids, fats, oils, and grease. This water generally contains high organic content that encourage the growth of bacteria. Also, the high fat and solid content cause problems for filtration and pumping. Generally, it is recommended that kitchen water be directed to the sewage system. Other potential greywater sources include swimming pools and collected rainfall runoff.

However, some places consider the level of bacteria in the kitchen wastewater can be considered safe, and should not be automatically ruled out for greywater reuse. In fact, there are examples of long-term reuse of kitchen sink water with no adverse effects on the garden plants as reported in [9]. It is to be noted that some contents of the kitchen water are useful for growing plants. Therefore, the treatment system of the kitchen water in high rise buildings should be treated separately if it is intended to reuse it in irrigation purpose. Otherwise, it can be collected with other grey water to be treated by a suitable system.

The amount of greywater produced from different sources are varies from place to another. According to this research, approximately 61% of the total wastewater produced by an average household or high rise buildings can be used as greywater. The kitchen wastewater is not usually included in this amount as it requires additional treatment in a domestic greywater treatment system before it can be reused. Table (2) indicates the total amount of wastewater and greywater produced in a typical house. The information in this table can be used in the design of greywater treatment system for a public or high rise building in Kuwait country.

Table (2) Total amount of wastewater and greywater produced from a typical house.

Wastewater Source	Total wastewater		Total Greywater	
	Liters per day	% Total	Liters per day	% Total
Toilet	186	32	--	--
Hand Basin	28	5	28	7
Bath/shower	193	33	193	48
Kitchen	44	7	44	11
Laundry	135	23	135	34
Total	586	100	400	100

Separation and Collection of Greywater

A piped system requires less user intervention and is more ideal from a public health perspective since it eliminates contact between the greywater and user. In this case, a plumbing network simply takes this water, keeping it separate from the pure water, and directs the greywater to a point where it can be stored, treated and reused. On the other hand, the black water made up of the wastewater from the toilet and the dark greywater from the kitchen (in many cases) are allowed to flow directly to the septic tank or to the sewer of municipal wastewater system. Black water is grossly contaminated by human excrement and requires a detailed treatment process such as a composting toilet before it is suitable to use in the garden.

The design of collection systems varies from country to another, but they are generally gravity collection systems and use ordinary plumbing components. In new buildings, the installation of such a 'dual-plumbing' system to perform separation and collection of greywater is simple and requires little extra expense as shown in Fig. 1. However, retrofitting such a dual system into an existing building may require more difficult installation work, depending on its design and the plumbing system.

However, many modern high rise buildings all over the world and in Kuwait already have dual-plumbing piping system similar to that shown in Fig. 1. In many cases, the existing piping system can be converted easily without much additional cost to a dual-plumbing. It is recommended that all new high rise buildings in Kuwait should have such a dual-plumbing system to make use of the produced greywater in the future.

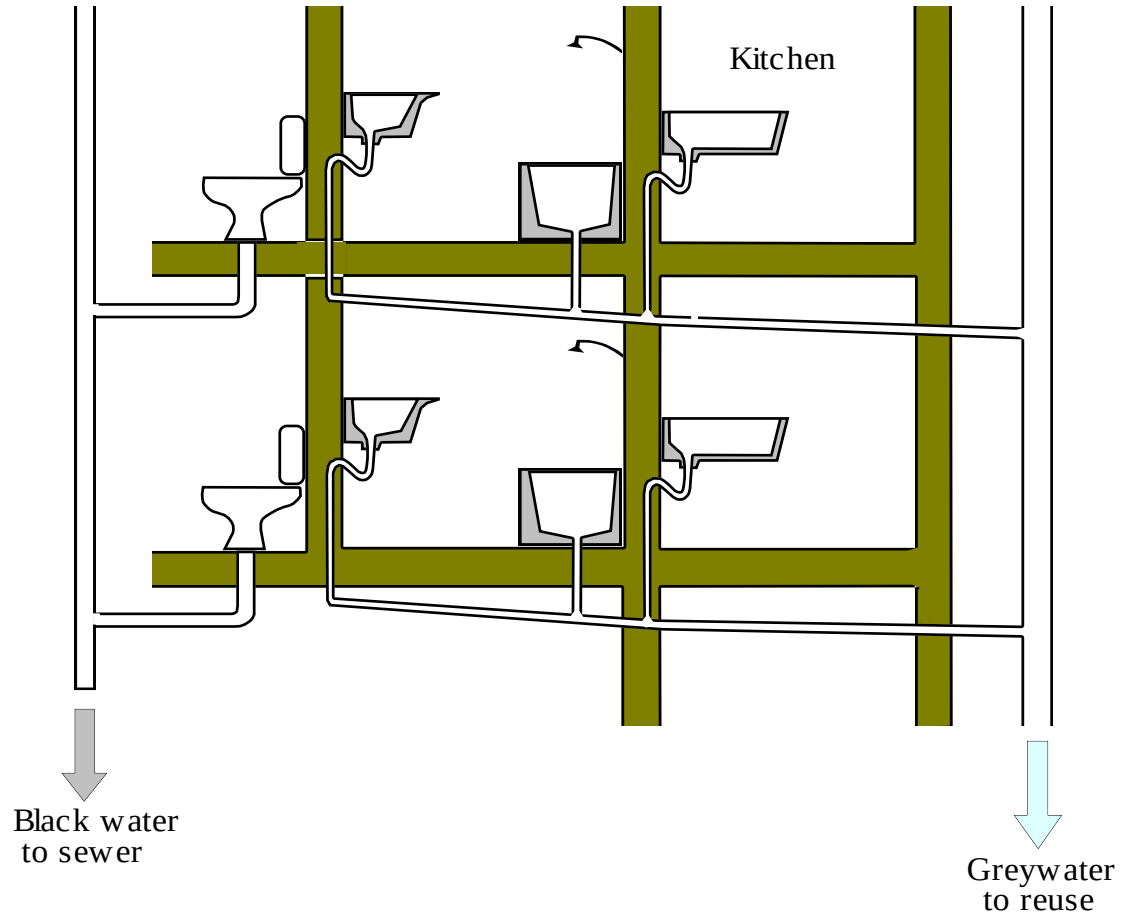

Fig. 1. Separation of greywater in a simple dual-plumbing system.

Treatment of Grey water

The Treatment of greywater may include the following:

1- Removing substances which are harmful to plants.
2- Removing materials which may be harmful to health.
3- Removing chemicals that have a negative impact on the environment.

4- Removing solid materials that may clog the piping system.

Minimum Treatment of Greywater

Many of the substances contained in greywater are not harmful to plants, and some are actually plant nutrients. Some of the substances in this water are actually very well treated if used in a healthy soil. In this case, the human contact with the greywater must be minimized. This can be attained by eliminating the need for user intervention in the system, and by reducing the contact at the irrigation stage. Then the risk to human health is very small.

A good soil can deal with low concentration of organic material, and also with soap constituents that may exist in the greywater. Simple greywater system has been successfully operating in many places all over the K uwait country for over 2 years. No detrimental effect on the garden plants has been observed after this period of operation. The greywater source has been chosen to minimize the amount of contamination that enters the system only water from one bathroom, bathtub shower and hand basin is used. The system is gravity fed throughout, eliminating the need for pumps.

Filtration

The first level simple treatment is the filtration. The best filter must be able to prevent solid materials, hair, clothes and food particles from entering the greywater system. In its simplest form, this could be a stocking or sock filter on the inlet pipe to the storage tank, or a more complex sand, stone and gravel media filter as shown in Fig. 2. If the kitchen sink water were to be used, a grease trap to remove fats and grease is necessary to prevent filter clogging.

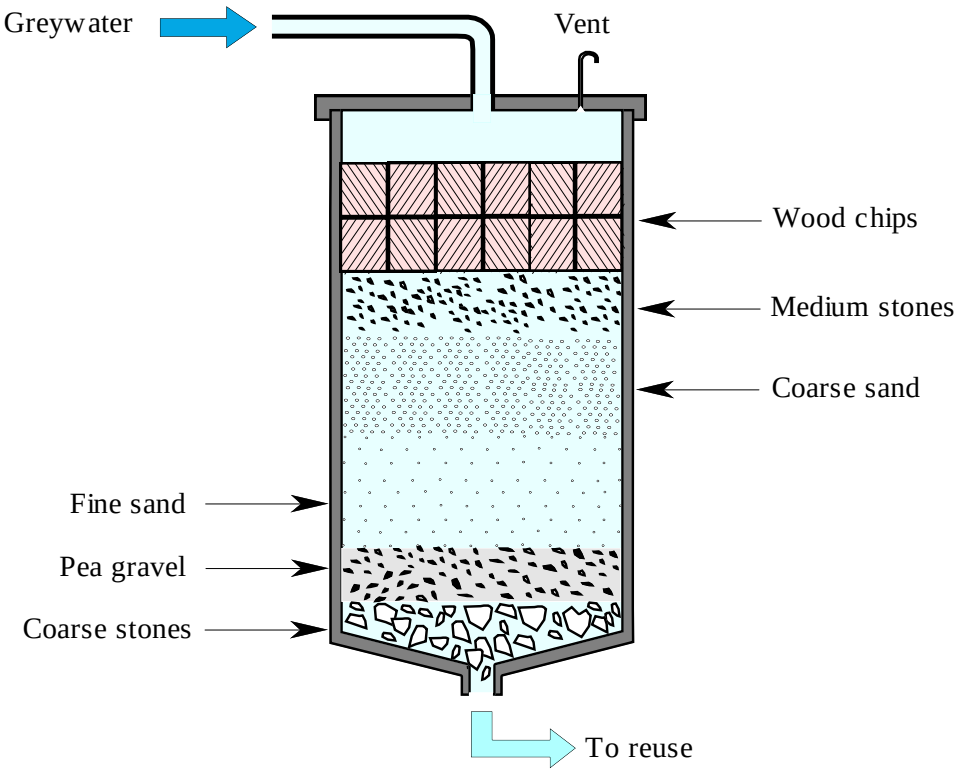

Fig. 2. Sand, stones and gravel media filter.

A number of sources such as Ludwig [10] propose the use of a natural mulch basin filled with stones and organic mulch (leaves, tree bark, etc) to filter and treat the greywater. 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 greywater. 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 greywater. 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 greywater.

Settling/Storage Tank

A settling tank is sometimes recommended as a means of removing solids and fats from the greywater. Substances denser than water will gradually fall out of suspension to the bottom of the tank (by gravity). On the other hand, grease, oils, soap and other lighter particles will float to form a surface scum layer and removed out of the greywater. The remaining liquid can then be reused. The settling tank also has the advantage of allowing hot water to be cooled before reuse. Figure 3 shows a simple greywater settling/storage tank which is usually constructed over the ground level. The tank size is decided according the greywater output rate and the reuse schedule.

On the other hand, Fig. 4. shows a complex automated greywater system with storage tank, filtration, backwashing, pumping and associated controls and valves. This system is proposed by Ludwig [10] and was found to be reliable, but costly (between $1,100 and $8,000) to install. Few applications will warrant such complexity and expense.

The settling/storage tank is usually fixed above the ground level such that both the lighter and heavier substances flow out, to the sewer piping system, easily by gravity. The tank wall and dimensions should be designed to allow time for heat transfer with the surrounding and separation of unwanted substances from the greywater.

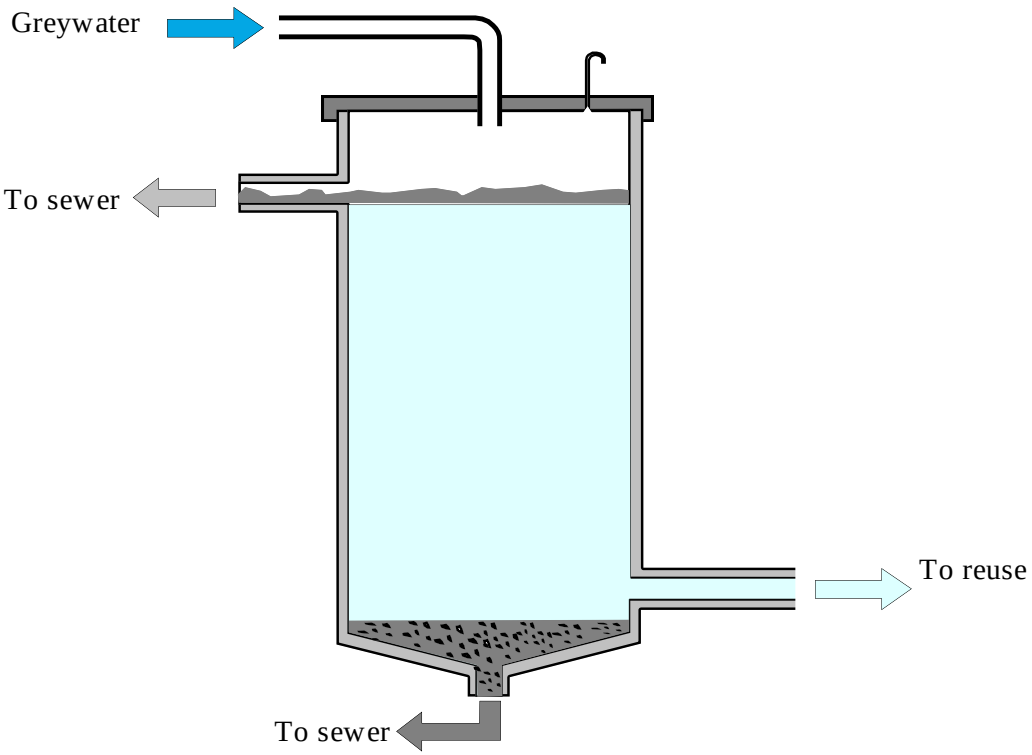

Fig. 3. Typical settlement/storage tank.

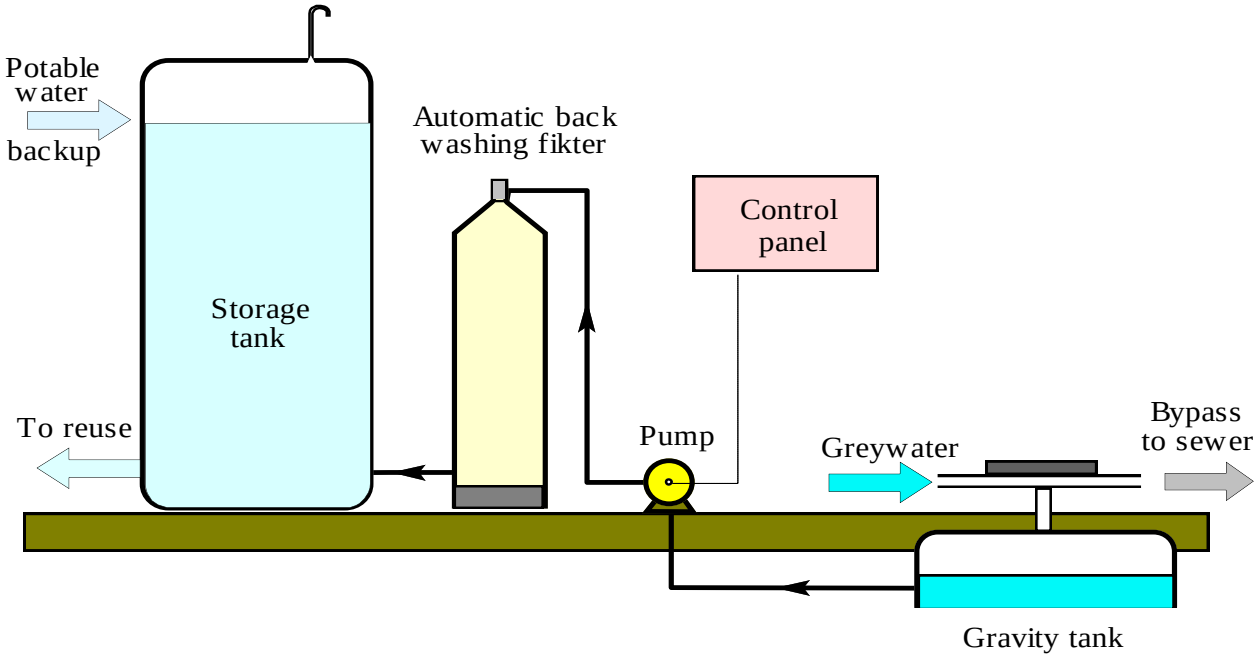

Fig. 4. Example of an automated greywater treatment system.

These systems usually contain a degree of automatic control depending on their size, greywater and output water quality. For a domestic small system little control is required. Sometimes manual control is enough. For medium and large buildings, a sophisticated control system is required. Figure 5 show a photograph of a commercial fully automatic system that can be built to deliver from 10 GPM to excess of 200 GPM output flow. This system contains a host of system accessories including turbidity monitoring, delivery system booster pumps, and more. The system is equipped with a high quality polyethylene storage tanks, for dirty raw and clean (treated) greywater, with backwashing filters and ozone treatment for the near complete removal of hair, skin cells, soaps, shampoos, detergents, and organic matter. The system also contains a high quality pumps with residual chlorine and/or dye injection systems and fresh water bypass or tank fill mechanisms.

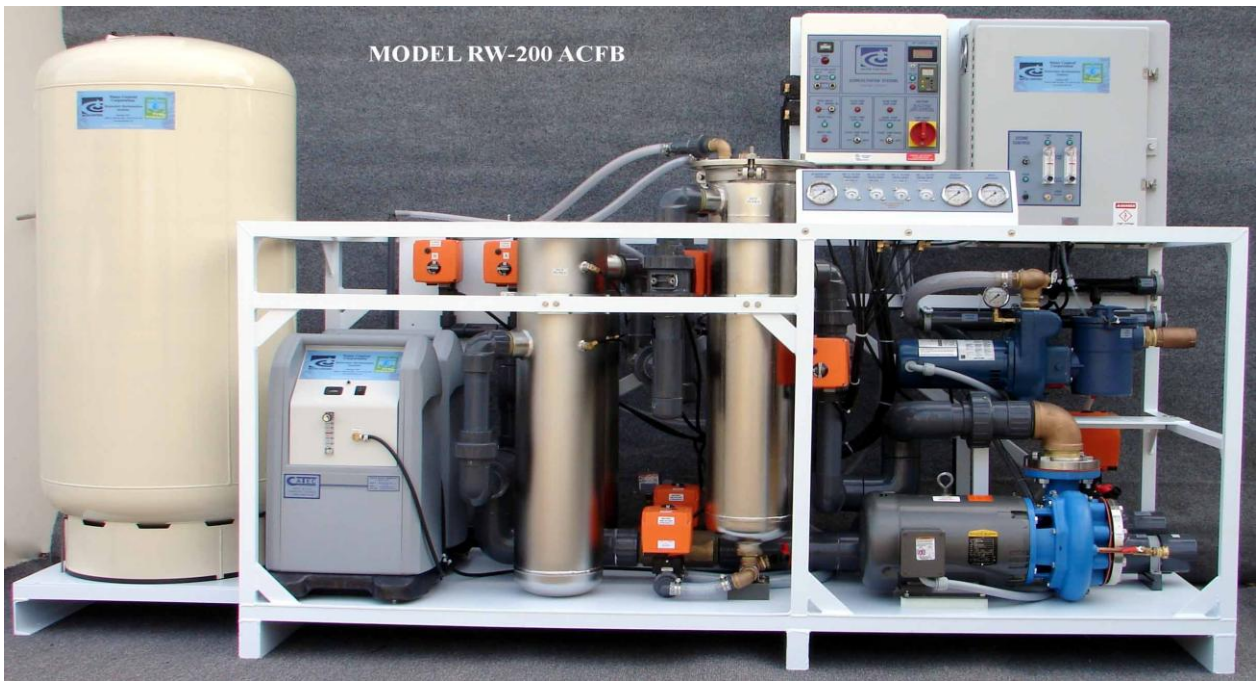

Fig. 5. A commercial greywater reuse system (www.catec.com) [11].

Disinfection of Greywater

Disinfection of greywater is an important and necessary process of treatment. It is often to add chlorine with a concentration of 0.5 parts per million to the greywater storage tank. The UV radiation or ozone can also be used with the greywater, 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 greywater that has been left standing and has begun to digest.

However, unless there is risk of human contact with the greywater, 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, but the presence of chlorine or other disinfection agents in the greywater may cause problems to plants and soil.

Water with dissolved chlorine takes at least 12 hours, to allow evaporation of the chlorine. Greywater systems with 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 greywater, 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 greywater, and who takes a fairly active role in caring and tending for their own plants. The cleaner the greywater 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 greywater, and how it is used. However, this relatively complex system requires more maintenance, and is more expensive.

IV. CONCLUSION

The main trend of this research refers to the efficiency of reusing process of grey water except from kitchens and dish washers.

V. RECOMMENDATION

It's recommended to carry out many experiments to fulfill the needs to reuse the black water because of scarce of water resources and also due to climate changes, especially in arid countries such as Kuwait country.

REFERENCES

[1] Many web-based publications.
[2] Center for the Study of the Built Environment (CSBE), "Greywater reuse in other countries and its applicability to Jordan", Project funded by Ministry of Planning Enhanced Productivity Program, 2003.
[3] Water Conservation Alliance of Southern Arizona 2000, Residential Greywater Reuse, Tucson: Water conservation alliance of southern Arizona (Water CASA), Retrieved June, 2003, from http://www.watercasa.org/research/residential/resindex.htm.
[4] Jeppesen, B.; and Solley, D. 1994. Domestic Greywater Reuse: Overseas Practice and its Applicability to Australia. Research report No. 73. Brisbane: Urban Water Research Association of Australia.
[5] Kambanellas, C. A. 1999. Cyprus Report for CEHA Regional Workshop on Water Conservation and Reuse: Important Elements of Water Resources Management Strategies, Amman, Jordan. Nicosia: Department of Water Development.
[6] Leggett, D. J.; Brown, R.; Brewer, D.; Stanfield, G.; and Holliday, E. 2001a. Rainwater and Greywater Use in Buildings, Best Practice Guidance. Report No, C539. London: CIRIA, Department of Trade and Industry.
[7] Hanson, L. 1997. Environmentally Friendly Systems and Products. Water Saving Devices. Bracknell: BSRIA, Department of Environment, Transport and the Regions.
[8] http://network.idrc.ca/ev.php
[9] www.oasisdesign.net
[10] Ludwig, A. 1994 - 2000. Create an Oasis with Greywater. Santa Barbara: Oasis Design.
[11] **www.catec.com**.