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The potential for reusing grey water and its generation rates for sustainable potable water security in Kuwait

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ABSTRACT

This study was conducted to achieve the following objectives: (1) to investigate the water consumption patterns of Kuwaiti households, (2) to determine the per use water consumption rate for plumbing fixtures and their frequency of daily use and (3) to estimate the amount of grey water generated per person per day to explore the potential for reusing grey water in Kuwait. To achieve these objectives, a preliminary study was conducted to determine the per use water consumption rate for each plumbing fixture. An intensive study was then conducted using data from 53 households in different districts in Kuwait. The average daily freshwater consumption rate per person was found to be 283 L, half of which was converted to grey water. Reuse of grey water could reduce the freshwater consumption and hence wastewater treatment by 72.73 million imperial gallons per day (MIGD), which could lead to a savings of KD 87.6 (US $318.55) million from the annual freshwater production budget and between KD 15.93 (US $57.92) and KD 27.08 (US $98.46) million from the annual wastewater treatment budget.

Keywords: Grey water; Kuwait; reuse.

INTRODUCTION

Kuwait is a country with a dry climate and very limited fresh water resources. It has an area of 17,820 km^2 and a population of 3,484,881 (KICI, 2009). Kuwait's single source of potable water is groundwater, from which wells draw only 1 million imperial gallons per day (MIGD) of water. The current consumption rate is 350.2 MIGD (102.04 IG/d/capita) (Statistical Year Book, 2009). This rate is considered very high compared to other countries. The average water consumption per capita per day is 47 L (10.34 IG) in Africa, 85 L (18.7 IG) in Asia and 334 L (73.48 IG) in the United Kingdom (West, 2006). The deficiency in potable water supply is compensated by seawater distillation. In Kuwait, there are 6 major seawater distillation plants that have a maximum production capacity of 423.1 MIGD. Currently, these plants produce 330.5 MIGD of distilled water, which meets 94.2% of the country's fresh water demand. Considering Kuwait's population growth rate (5.25% annually in the past 10 years) (Al-Jarallah and Al-Fares, 2009) and economic development (4.4% growth in 2011) (Hasan and AlGharaballi, 2011), the demand for fresh water is expected to increase rapidly. If the consumption rate is the same in 5 years, the distillation plants will reach their maximum capacity. Therefore, it is imperative that immediate action be taken to preserve water resources and reduce water consumption to prevent water shortage crises in the future (Al-Jarallah and Al-Fares, 2009).

During the past few years, the Kuwaiti government has initiated some significant measures to reduce water consumption. In 2008, the Ministry of Electricity and Water implemented a national public awareness program called the "Tarsheed" project, which aims at enlightening the public regarding the water situation in Kuwait and increasing public awareness about water conservation and how the public can help in achieving it (National project to rationalize energy, 2008). In the same year, the Kuwait Institute for Scientific Research distributed one million aerating faucets (which mix air with water) to 60,000 households to help reduce water consumption. This initiative resulted in a savings of 16.65 IGD, which is equivalent to 15 million KD per year. However, the most important water conservation measure that the Kuwaiti government has implemented was reusing treated wastewater for irrigation purposes. In Kuwait, 70% of domestic freshwater consumption results in wastewater production. This wastewater is treated in 4 wastewater treatment plants that together produce 126 MIGD of treated effluent, of which 56 MIGD is tertiary [KD 0.6 (US $2.18) per 1000 IG] treated and is used in landscaping; the remaining 70 MIGD is quaternary treated [KD 1.02 (US $3.71) per 1000 IG] and is used for agricultural irrigation. This program achieved great success. Thus, the demand for low-cost treated wastewater increased rapidly and exceeded the production levels (Al Habashi, 2009). The door is now wide open to take a further step and incorporate more aggressive wastewater reuse strategies in daily life activities.

BACKGROUND

Kuwait is heading toward water crises. In a few years, the amount of fresh water produced will not be sufficient to meet the demand. Indeed, the shortage of fresh water is becoming a global problem. With the impact of climate change and the continuous increase in the global population, the pressure on the fresh water supply is increasing significantly. This issue has caused the scientific community to explore alternative water sources, such as wastewater reuse (Revitt *et al.*, 2011). Special attention has been given to " grey water" treatment and reuse. Grey water is wastewater generated from showers, baths, bathroom sinks and washing machines (Allen *et al.*, 2010). It mainly contains soap residues and possibly some human pathogens (Nolde, 1996), which make it suitable for on-site treatment and reuse (Revitt *et al.*, 2011). Treated grey water is suitable for car washing, yard washing or even clothes washing, but the two most common uses are toilet flushing and landscape irrigation (Abusam *et al.*, 2007). Nevertheless, grey water should never be used for dust control, cooling, spray irrigation or any other use that could result in airborne droplets or mist (CSBE, 2003).

Grey water treatment and reuse practices have already been studied and applied in many countries around the world. However, their importance is greater in countries that suffer from water shortages, such as Australia and countries in the Middle East (Revitt *et al.*, 2011). The grey water generated as a percentage of the total water consumption differs from one country to the next based on age, gender, living standards, habits and the degree of water abundance (Mourad *et al.,* 2011). In Australia, 50% of the water consumed is transformed into grey water and reused in toilet flushing and irrigation, reducing the total water consumption by 29% (Revitt e*t al.*, 2011). In Syria, 35% of the water consumed is saved by treating and reusing grey water for toilet flushing and grey water comprises 46% of the total water consumption (Mourad *et al.,* 2011). However, in Oman, due to the hot climate, which is similar to Kuwait's, the grey water generation rate was found to be 82% of the total freshwater consumption, with shower, kitchen, laundry and sink use accounting for 58%, 29%, 8% and 5% of the grey water use, respectively.

Untreated grey water is characterized by odor, color and pathogens; therefore, it must be filtered and disinfected prior to being reused (Mourad *et al.,* 2011). Grey water treatment systems are classified in three categories: diversion systems, physical treatment systems and biological treatment systems (Environment Agency, 2011). Selection of a treatment system is based on the ultimate use. A diversion treatment system is sufficient for toilet flushing and landscape irrigation only. The grey water is filtered and then pumped directly into the toilet tank and/or irrigation system (Rensburg and Griffioen, 2010). In a physical treatment system, the grey water is treated through filtration and disinfection processes to reduce the concentrations of bacteria and other micro-organisms that may multiply in stagnant water. This type of system allows the treated water to be stored for use in car and yard washing. A biological treatment system is a physical treatment system with the addition of an aeration zone and membrane bioreactor. This system reduces the microbial and organic concentrations significantly, making the water suitable for laundry uses (Leal *et al.,* 2007).

While water conservation is the main goal of grey water reuse, the separation of grey water from black water in the domestic sector could lead to the use of smaller septic tanks in wastewater treatment plants to lower treatment costs, provide relief for wastewater treatment plants from organic and hydraulic overloads and minimize groundwater contamination potential. Furthermore, reuse of grey water for irrigation could conserve nutrients (nitrogen, phosphorus and potassium) that would otherwise be lost if the grey water were discarded in the wastewater system (Capital Regional District, 2004).

Grey water treatment and reuse are appealing because they decrease the freshwater demand, thus reducing the cost associated with generating freshwater and treating wastewater. However, members of the public tend to fear grey water treatment and reuse because they are concerned about its consequences for their health. They worry about diseases and infections that they could catch from grey water (Ottoson and Stenstrom, 2003). This concern could be eliminated if treatment systems were installed, used and maintained properly. In the Middle East and North Africa, some Muslims believe that treated grey water is not pure and is thus not suitable for ablution purposes (McNeill *et al.*, 2009). However, in 1978, the Council of Leading Islamic Scholars issued a fatwa (ruling) that appropriately treated grey water could be considered pure, thus paving the way for its reuse (Pandya *et al.*, 2012).

OBJECTIVES

The objectives of this research study are to achieve the following: (1) to investigate the water consumption patterns of Kuwaiti households, (2) to determine the per use water consumption rate for plumbing fixtures and their frequency of daily use and (3) to estimate the amount of grey water generated per person per day to explore the potential for reusing grey water in Kuwait.

METHODOLOGY

To achieve the aforementioned objectives, the study was divided into two phases: a preliminary phase and a main phase. The preliminary phase was aimed at facilitating the main phase with the figures and rates needed, i.e., the amount of water consumed per use for each plumbing fixture. The research required in the preliminary phase was conducted using data from randomly selected households. The number of samples surveyed differed depending on the type of the plumbing fixture investigated. Plumbing fixtures whose water consumption depends primarily on user habits, such as showering, had a large number of samples (130 samples), while ones whose water consumption is controlled by the manufacturer, such as washing machines, had a smaller number of samples (47 samples).

The water flow rate was calculated for each activity by dividing the volume of an N-liter sample by the average time required to fill an N-liter sample. Many toilets tanks in the sampled households were hidden inside of the walls, which made it hard to determine the amount of water consumed per use. Thus, plumbing fixture vendors were surveyed to collect information about the typical capacities of the toilet tanks available in the market and calculate the average water quantity consumed every time a toilet is flushed. Table 1 shows the details for plumbing fixtures and the parameters used to estimate water quantities per use.

Table 1: Different parameters used to determine quantity per use values

Plumbing Fixture		**Parameters for calculating Water Quantity per Use**			
		Flow Rate	**Duration**	**Frequency of use**	**Other**
Bathroom Sink			x	x	x
Showering			x	x	x
Toilet Flushing					Survey vendors
Bathroom Hose		x	x	x	
Kitchen Sink		x	x	x	
Dishwashing		x	x	x	
Cooler		x	x	x	
Filter		x	x	x	
Clothes Washing	**Washing Machine**				Survey vendors, Capacity
	Hand Washing	x	x	x	
Yard Washing					Estimated based on previous study
Car Washing					Estimated based on previous study

In the main phase of the study, a survey was conducted using a questionnaire designed and distributed to estimate potential grey water quantities in Kuwait. Resident households with different lifestyles and standards of living were surveyed. The details of their daily water consumption habits were recorded on a daily basis during weekdays and weekends. To ensure the reliability of the results, a confidence level of 90% with a margin of error of ± 11.3 was used. A total of 53 households were studied and each household provided a large number of data points corresponding to plumbing fixture uses by occupants of the home. In this manner, results representative of the population of Kuwait were obtained. To ensure proper data collection and high-quality results, a demonstration program was conducted in every sampled household. One family member from each of the 53 houses was trained via a comprehensive program to be responsible for following up on data collection, giving assistance to his/her family members and acting as the contact person with the research team.

A questionnaire was drafted and pretested several times to ensure its clarity and simplicity. Respondents were asked a series of multiple-choice questions pertaining to their sociodemographic characteristics (e.g., age, income, level of education, number of household members, type of residence, governorate of residence and number of servants) and water consumption habits (e.g., washing duration and frequency for all types of washing, washing machine capacity, frequency of use, car and yard washing method, duration and frequency).

The data collected were analyzed with respect to the day of the week (weekdays and weekends) and room type (bathrooms, kitchen, laundry and yard). The average frequency of daily use per capita for each plumbing fixture was then determined. This rate was calculated using the following equations:

$$\text{Frequency of daily use/capita for each house} = \frac{\text{Frequency of daily use of the fixture}}{\text{Number of residents in the house}} \quad (1)$$

$$\text{Avg. frequency of daily use/capita} = \frac{\text{Frequency of daily use/capita for each house}}{\text{Number of houses}} \quad (2)$$

Further analyses were carried out to calculate the average daily water consumption per capita for each plumbing fixture (by multiplying the rates obtained from the preliminary phase of the study with the corresponding rate for frequency of use obtained from the main phase of the study).

The consumed water was classified into three types wasted, black and grey - depending on the nature of the water produced. Wasted water is water that is used by the consumer and does not go into the household sewage system, such as the water used for cooking, planting and car washing. Black water is the wastewater from toilets and kitchen sinks that contains urine, fecal matter and high levels of nutrients. The remaining water is considered grey water. The collected data were also used to determine the daily production rate of each type of water.

The water consumption patterns in Kuwait were analyzed and compared to those of some other countries. Environmental and economic impacts associated with implementing grey water reuse were also investigated.

RESULTS and DISCUSSION

The preliminary phase of the study was conducted to determine the amount of water consumed per use for each type of plumbing fixture listed in Table 2.

These plumbing fixtures were classified according to their location in the house (bathroom, kitchen, laundry and outdoor activities) and their end water type (grey, black and wasted). The results of this study are shown in column 2 of Table 2. The data obtained showed that car washing consumed the highest amount of water per use, followed by washing laundry and showering. However, the water consumption per day depends on both the amount of water consumed per use and its frequency.

Table 2: Results of the preliminary and main phases of the study

Pluming Fixture		Water Consumed	End Water Type	Frequency of Use / Cap.d			Qty. of Water Consumed L/Cap.d
				Min	Avg.	Max	
Bathroom	Bathroom Sink	1.20 L/use	Grey	2.17	5.76	13.22	7.00
	Shower	122.00 L/use	Grey	0.21	0.95	2.58	116.00
	Toilet	6.00 L/use	Black	1.05	4.20	8.90	25.20
	Hose	0.25 L/use	Black	1.38	4.35	9.55	1.10
Kitchen	Dish washing	64.30 L/use	Black	0.25	0.63	0.86	40.50
	Filter	3.00 L/use	Wasted	0.00	0.71	4.47	2.00
Laundry	Washing Machine	62.00 L/use	Grey	0.03	0.24	1.49	15.40
	Hand Wash	22.00 L/use	Grey	0.00	0.26	1.02	5.10
Outdoor Activities	Planting	3.50 L/m^2	Wasted	0.00	2.78	37.04	9.70
	Car Wash	189.00 L/use	Wasted	0.00	0.20	1.38	38.00
	Yard Wash	6.16 L/m^2	Wasted	0.00	3.73	53.57	23.00

The preliminary investigation was followed by the main phase of the study, using 53 households, which included apartments and villas, distributed among the 6 governorates of Kuwait. The results of the analysis indicated large discrepancies in water use patterns between apartments and villas. Because the majority of Kuwaitis live in villas, for consistency and reliability of the results, the apartment samples were excluded and the analysis was conducted using only the 37 questionnaire samples obtained from the villas, which provided a ±13.5% margin of error at the 90% confidence level.

The average frequency of daily use per capita for each plumbing fixture was calculated using Equations 1 and 2 and the results are shown in column 4 of Table 2. From the table, it can be observed that on a daily basis, the bathroom sink was the most frequently used plumbing fixture, with a rate of 5.76 uses per capita, followed by the bathroom hose and toilet flushing, with 4.35 uses per capita and 4.2 uses per capita, respectively.

The per capita amount of water consumed per day was then calculated for each plumbing fixture by multiplying columns 2 and 4. The results are shown in column 5 of Table 2 and in Figure 1.

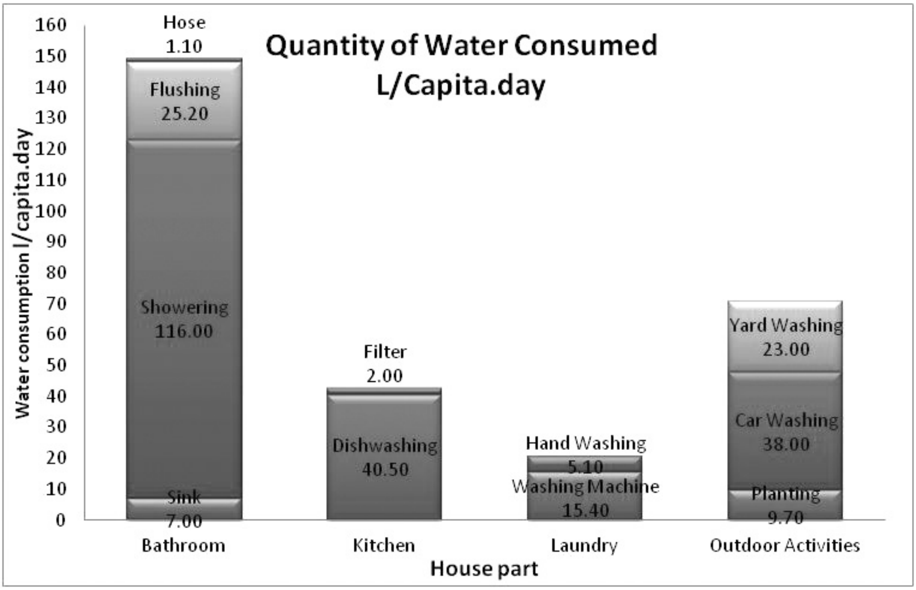

Fig. 1. Quantity of water consumed for different plumbing fixtures.

After detailed analysis of the data, the average daily water consumption rate per capita (indoor and outdoor activities) was found to be 283 L, of which 75% was attributable to indoor uses. As shown in Figure 1, the bathroom had the highest water consumption rate, while the laundry had the lowest. The analysis also showed that the uses that consumed the most water in the bathroom, kitchen, laundry and outdoors were showering, dishwashing, clothes washing by machine and car washing, respectively, while the uses that consumed the least amount of water in the bathroom, kitchen, laundry and outdoors were use of the bathroom hose, use of the kitchen filter, clothes washing by hand and planting, respectively. Table 3 shows a comparison of the water consumption by plumbing fixtures as percentages of the total indoor water consumption for Kuwait, the United States (US), Brazil and Oman.

Table 3: Indoor water consumption rates for different countries (Vickers, 2001, Ghisi and Oliveira, 2007, Prathapar *et al.*, 2005)

Plumbing Fixture	Kuwait	USA	Brazil	Oman
Filter	1.00%	NA	NA	5.43%
Dish Washing	19.00%	1.62%	20.75%	26.16%
Bathroom Sink	3.00%	15.70%	4.85%	4.51%
Toilet	12.00%	26.70%	28.00%	4.35%
Hose	1.00%	NA	NA	
Shower	55.00%	18.50%	39.20%	51.42%
Washing Machine	7.00%	21.70%	7.20%	8.13%
Hand Wash	2.00%	NA	NA	
Other Domestic uses	NA	2.20%	NA	NA
Leaks	NA	13.70%	NA	NA
Total indoor water consumption (L/Capita/d)	212.30	226.00	156.00	152.00

Comparing Kuwait's per capita water consumption rate with that of the US, it can be observed that the percentage of water used in the shower in Kuwait was reported to be almost triple the rate in the US, which may be due to the hot and dusty weather in Kuwait, compelling people to shower almost every day. Additionally, water consumed in dishwashing in Kuwait is 11 times greater than that of the US. This significant difference could be due to differences in eating habits and the use of disposable kitchenware in the US, where less water is required for dishwashing. In the US, a dishwashing machine is used to wash the dishes, whereas in Kuwait, dishes are washed by hand, mostly by housemaids, who are not particular about conserving water. In contrast, the water consumption percentage for washing machines in the US is reported to be triple that of Kuwait. Undeniably, Kuwait is a high-income country, which has provided most Kuwaitis the advantage of a luxurious lifestyle. They are able to afford sending their laundry to dry cleaning shops, thereby reducing household washing chores. Other activities that consume a great quantity of water that are not mentioned in Table 3 are car washing, yard washing and planting. As indicated in Table 2, car washing, yard washing and planting consumed 70.7 L/capita.d. This high water consumption rate may be associated with a high income level; the high-income group can occupy houses that are elegantly furnished, with beautifully landscaped gardens and a car park with a large collection of cars. Another factor that could contribute to the high water consumption rate is the arid climate in Kuwait that causes frequent sand storms, necessitating frequent outdoor washing activities.

The plumbing fixtures were classified according to their end water types produced, such as grey, black and wasted water (Figure 2). Dishwashing was found to be the major source of black water generation, while wasted water was found to be mainly produced from car washing. More importantly, the results showed that grey water comprised 51% of the total wastewater produced in Kuwaiti households, which is equal to almost 143.5 L/capita daily, with showering being the main source of grey water. Although Kuwait is a developing country, its rate of grey water generation is considered high and falls within the range of some developed countries (Table 4).

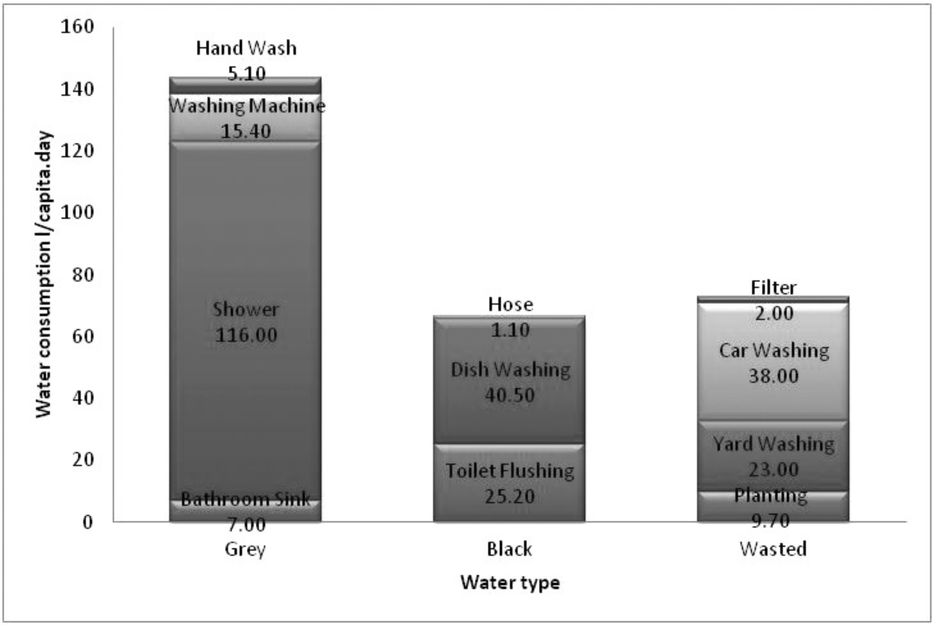

Fig. 2. Plumbing fixtures classified according to end water type.

Table 4: Grey water generation rate for different countries (Friedler and Hadari, 2006)

Location	Volume (L/capita day)
Developing Countries	20-30
China, ecological sanitation	80
India, Madhya Pradesh	13-33, with a mean value of 23
USA	200
Australia	112
Belgium	85
Norway	81-112
Sweden	66-110
Germany	33-65

The data were also analyzed to investigate the effect, if any, of the day of the week (weekday versus weekend) on the consumption pattern. The results shown in Figure 3 confirm that for all sources of grey water, there were no significant differences for weekdays versus weekend days.

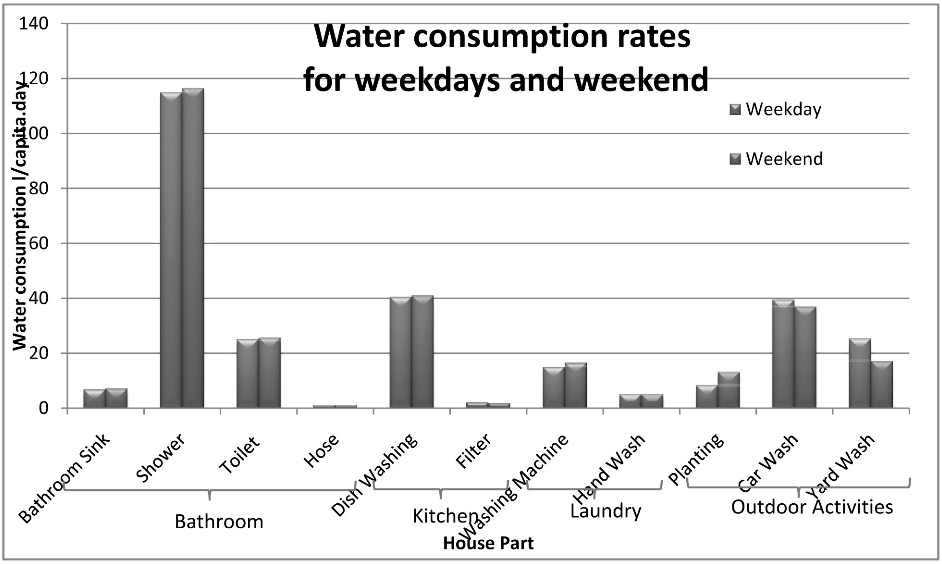

Fig. 3. Water consumption rates for weekdays and weekend.

The latest statistical year book published by the Ministry of Electricity and Water states that the average daily water consumption rate is 102.04 IG/capita (464 L/capita). This rate is calculated by dividing Kuwait's total water consumption by the population. Thus, it includes the per capita water share of all the water-consuming sectors (domestic, industrial and agricultural). However, actual individual water consumption is represented only by the domestic sector share, which is almost 64% of the total water consumption rate (Alhumoud and Madzikanda, 2010), making the per capita daily water consumption in households equal to 297 L. This is only 5% higher than the total obtained in this study (283 L), which supports the accuracy of the study results.

A daily water consumption of 297 L/capita is considered to be quite high (WBCSD, 2005). The low cost of fresh water plays a major role in raising the consumption rate. It is a known fact that most of Kuwait's commodities are subsidized by the government, including fresh water. The actual production cost of 1,000 IG of freshwater is KD 3.3 (US $12) but costs the consumer only KD 0.96 (US $3.50) (Al Habashi, 2009). Other than the cost of the water, previous studies have shown that lack of awareness and dependence on housemaids, who do not comprehend the value of water, to do household chores, such as cleaning, washing and cooking, have caused a significant increase in the water consumption rate (Al-Jarallah and Al-Fares, 2009). In addition, the majority of households use fresh water for planting, gardening and washing their yards and cars instead of brackish or grey water (Fadlelmawla and Al-Otaibi, 2005). Apart from the luxurious lifestyle and the low price of water, the arid climate and hot temperature in the country increase the overuse of fresh water by the residents.

The high consumption rate may be balanced and even reduced by implementing grey water reuse. The quality of grey water influences the level of treatment needed and thus the budget allocated and ultimate use options. grey water may contain diluted or suspended waste or even pathogens and microbial microorganisms. Studies have shown that the characteristics of grey water vary widely from one household to another (Table 5) depending on the number of occupants, their lifestyle habits and ages, the sources of water, its usage patterns and the type of soaps, shampoos and detergents used (Australian Capital Territory, 2007). Thus, grey water was accepted to be used for certain activities such as toilet flushing, planting, car washing and yard washing with or without preliminary treatment (Nolde, 1999; March *et al.*, 2004; Hatt *et al.*, 2006). Reusing grey water for such activities will save approximately 96 L/capita of fresh water. The excess amount of grey water may be collected by municipalities to be treated and reused in a wide range of applications, such as landscaping, crop irrigation and street washing (Prathapar *et al.*, 2005; Hatt *et al.*, 2006; Baker & McKenzie LLP, 2008).

Table 5: Grey water quality parameter ranges (Prathapar *et al.*, 2005, Godfrey *et al.*, 2010, NSW Government, 2008, Jamrah and Ayyash, 2008, Assayed *et al.*, 2010, Raude *et al.*, 2009)

Parameter	Unit	Grey water	
		Range	Mean
Suspended Solids	mg/L	40.00-810.00	425.00
Turbidity	NTU	15.00-444.00	229.50
BOD_5	mg/L	45.00-1610.00	827.50
Nitrate	mg/L	2.19-2.97	2.58
Ammonia	mg/L	0.10-9.30	4.70
Total Nitrogen	mg/L	2.00-340.00	171.00
Total Phosphorus	mg/L	0.10-13.10	6.60
pH		5.60-8.60	7.10
Conductivity	mS/cm	325.00-1140.00	732.50
Hardness (Ca&Mg)	mg/L	15.00-55.00	35.00
Sodium	mg/L	60.00-780.60	420.30
Faecal Coliforms	cfu/100 ml	$48*10^4$-$1.8*10^6$	$1.14*10^6$

Nationwide implementation of grey water reuse would conserve 72.73 MIG of freshwater every day. This decrease in water consumption would reduce energy consumption, as well as the production of gaseous and liquid pollutants by wastewater treatment and water desalination plants and would increase nutrient reclamation in the topsoil, thereby enhancing plant growth.

In addition to the environmental benefits, recycling grey water will lead to a reduction in fresh water consumption and thus a reduction in the production rate. This reduction will help overcome major water crises because the maximum water production capacity of all of the desalination plants combined is 423.11 MIGD, while the average consumption rate is 350.2 MIGD. Considering that the average annual population growth rate of the past 10 years has been 5.25%, unless significant action is taken, a major water crisis will be faced in the next few years. Utilization of grey water will delay the crisis but will not provide a solution to the crises. Furthermore, grey water reuse will decrease the production of fresh water by 72.73 MIGD, which will result in savings of KD 240 (US $872.74) thousand/d or KD 87.6 (US $318.55) million/year and decrease the treatment of wastewater by approximately the same amount, which will result in savings of between KD 15.93 (US $57.92) and KD 27.08 (US $98.46) million/year, depending on the treatment level (Al Habashi, 2009). Although installing a grey water treatment plant may incur some capital investment, the cost of installation would be alleviated by the savings that may be generated from grey water reuse. Either a grey water treatment system can be installed in each household or a large treatment unit can be allocated for each district to treat all grey water produced by the households of that region.

CONCLUSIONS

This study investigated the per use water consumption rate for plumbing fixtures in Kuwaiti households, the frequency of daily use, the amount of grey water generated and the percentage of contribution to total grey water production. The objective was to investigate the potential for reusing grey water in Kuwait.

The average daily freshwater consumption rate was found to be 283 L/capita, from which 143.5 L of grey water was produced. The results indicate that 51% of the total residential fresh water consumption was converted to grey water.

The implementation of grey water reuse will reduce both the fresh water consumption rate and wastewater generation rate by 72.73 MIGD, leading to a significant savings of KD 87.6 (US $318.55) million from the annual freshwater production budget and between KD 15.93 (US $57.92) and KD 27.08 (US $98.46) million from the annual wastewater treatment budget.

In conclusion, grey water was found to comprise the largest portion of wastewater generated by residential households and its reuse will enhance water management and lead to positive economic and environmental changes. Although this study focused on the use of grey water in residential buildings, the implementation of a similar water conservation strategy may be useful in educational, commercial, recreational, cultural and governmental facilities. Thus, further detailed studies should examine the quality of the grey water produced, the design of feasible grey water systems and the potential for application to facilities other than residential buildings.

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إمكانية إعادة استخدام المياه الرمادية وتقدير معدلات إنتاجها في دولة الكويت

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خلاصة

تهدف هذه الدراسة إلى تقييم إمكانية إعادة استخدام المياه الرمادية الناتجة من المنازل في دولة الكويت عن طريق تقدير كمية المياه التي يستهلكها الفرد الواحد ونوعيتها بعد استخدامها. وقد تم ذلك من خلال استبيان تم توزيعه وتطبيقه على 53 منزل من مناطق مختلفة. وقد وجد أن الفرد يستهلك 181,92 لتر من المياه العذبة يوميًا ليتحول 64٪ منها إلى مياه رمادية. حيث تشكل المياه الناتجة عن الاستحمام وغسيل السايارات وغسيل الفناء وغسيل الملابس ومغسلة الحمام 36٪ و 21٪ و 20٪ و 17٪ و 6٪ من كمية المياه الرمادية الناتجة، بالتتابع. إن اعادة استخدام المياه الرمادية من الممكن أن يؤدي إلى تقليل معدل استهلاك المياه العذبة ومعدل انتاج مياه المجاري بمقدار 22,57 مليون جالون امبريالي يوميًا، مما يترتب عليه توفير 27,204 مليون دينار كويتي من ميزانية انتاج المياه العذبة وما بين 4,95 و 8,41 مليون دينار كويتي من ميزانية معالجة مياه المجاري سنويًا.