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ONSITE GRAYWATER RECLAMATION AND REUSE IN URBAN COASTAL AREAS: IMPACT ON SALTWATER INTRUSION REVERSAL

by
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This study explored the reuse of graywater as a potential water supplement to meet shortages encountered along coastal urban areas, where saltwater intrusion is impairing coastal aquifers. Saltwater intrusion is a direct result of overexploitation of groundwater associated with increased demand due to population growth and development coupled with urbanization (less aquifer recharge) and exacerbated by climate change impacts (less precipitation, higher temperatures, and sea level rise). The objective of this research is to assess the potential of graywater reclamation and reuse in urban coastal areas, and to explore feasible techniques for implementation. For this purpose, a field survey questionnaire was developed and administered in a pilot area to characterize current water sources, uses, costs, public satisfaction and perception about water quality, wastewater recycling systems, and willingness to contribute in the installation of such systems. Groundwater samples were also collected from accessible wells to assess water quality and saltwater intrusion. Statistical analysis was performed to define factors that affect people's perception of graywater reuse and identify patterns that have management implications. The study concluded with management recommendations to integrate graywater recycling as a new source of water that can supplement existing water sources and help alleviate water shortages.

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CHAPTER 1
INTRODUCTION

With the increasing global water shortages (Eliasson, 2015), particularly the depletion of groundwater aquifers (Aeschbach-hertig and Gleeson, 2012; Beek et al., 2010; Groundwater Governance, 2015), a wide range of water management strategies were utilized targeting increased supplies or decreased demands (Poorman, 2007). On the supply side, efforts traditionally aimed to increase the amount of available freshwater through the exploitation of additional surface and ground water sources (FAO, 1993), or more recently through sea water desalination (Gleick, 2014; Lattemann and Höpner, 2008). However increased exploitation of water resources reduces available renewable sources and increases their vulnerability to saltwater intrusion, particularly in coastal urban areas (Barlow and Reichard, 2010; Mahesha and Lakshmikant, 2014). On the other hand, demand side management aims to reduce water demand through the efficient use and reuse of water resources (Poorman, 2007).

Wastewater reuse has the double advantage of reducing the pressure on surface and ground water exploitation, and minimizing wastewater discharge to surface water (European Commission, 2013), particularly untreated sewage that is often discharged without treatment into water bodies in many parts of the developing world (WHO/UNEP/UN-Habitat, 2015). In this context, broad applications for reuse have been developed subject to the level of treatment (EPA, 2012), with the most evident use being in agriculture and landscape irrigation since this sector consumes between 50 to 85% of the total water demand (Gleick, 2014). Another common application is domestic usage such as toilet flushing that consumes a large fraction of the domestic water demand (Campisano and Modica, 2010; March et al., 2004; Mayer et al., 1999; Nolde, 1999). Furthermore, groundwater recharge has been explored as a valuable approach for the restoration of groundwater levels and the control of saltwater intrusion into fresh water aquifers (Foster and Chilton, 2004; Gikas and Tchobanoglous, 2009; Lu and Leung, 2003). Industrial applications such as mixing with construction material also present a potential end use of recycled wastewater (Alqam et al., 2014; Asadollahfardi et al., 2016).

Wastewater treatment can either be conducted onsite through reuse using decentralized water reclamation units or off-site using centralized facilities. Decentralized reclamation offers the advantage of discharging the water in the watershed of origin, thus contributing towards its hydrological balance (O'Callaghan, 2008). Additionally, the water is managed by its users, the direct beneficiaries, who have an interest to maintain the continuity of the reclamation system. Meanwhile, centralized wastewater treatment is often considered more cost-effective owing to the economy of scale, but it offers less opportunity for reuse (Massoud et al., 2009).

Municipal wastewater can be divided into two main types namely blackwater and graywater (COP, 2010; EPA, 2012). Graywater is the water draining from household sinks, showers, and laundry. While kitchen water is often considered part of graywater, it is not recommended for household reuse because it contains large amounts of bacteria, fat, oil and grease (Eriksson et al., 2002; WHO-ROEM, 2006). On the other hand, blackwater is the remaining wastewater that contains human wastes and is thus characterized by even higher contaminant levels (Chaillou et al., 2011; Zeeman et al., 2008). Therefore, more treatment is required for the reuse of regular wastewater as compared to graywater (EPA, 2012; Jokerst et al., 2011; Santasmasas et al., 2013).

Graywater comprises a substantial amount (50 to 80%) of total residential wastewater, with reported daily volumes ranging from 15-44 L/capita (Nolde, 1999) up to 90-120 L/capita (Morel and Diener, 2006), rendering its onsite reuse a major relief to freshwater resources and wastewater treatment plants (Friedler and Hadari, 2006; WHO-

ROEM, 2006). Efficiencies may vary in accordance with consumption patterns, with reported savings reaching up to 50% (Campisano and Modica, 2010; City of Los Angeles, 1992; Friedler and Hadari, 2006; Mandal et al., 2011; Yu et al., 2014).

Graywater treatment techniques range from simple single-stage systems (for irrigation purposes) to advanced multi-stage systems required to achieve water quality that meets domestic reuse standards. Suitable graywater treatment technologies, that provide an effluent quality that meets toilet flushing standards, comprise a preliminary stage for screening/sedimentation, followed by a secondary treatment stage and disinfection to prevent technical problems (clogging/fouling) and avoid potential health risks (Li et al., 2009; Nolde, 1999). When discarding land-intensive treatments which are often unsuitable in urban setups, the most common secondary treatment options reported in the literature were rotating biological contactors (Abdel-Kader, 2012; Friedler et al., 2005; Ingman et al., 2009; Nolde, 1999), membrane bioreactors (El Hamouri et al., 2008; Friedler et al., 2006; Ingman et al., 2009; Memon et al., 2007; Winward et al., 2008) and depth filtration (Abudi, 2011; Al-Jayyousi, 2003; Assayed et al., 2015; Ingman et al., 2009; March et al., 2004).

Economically, graywater reuse systems are typically attractive options with payback periods ranging between 2-14 years (Table 1). The payback period is highly dependent on local water tariff structure, building size, treatment type and end use (Imteaz and Shanableh, 2011; Mandal et al., 2011). The feasibility of graywater reuse generally improves with growing awareness about water scarcity and the economic implications of environmental degradation, as well as the decreasing cost of treatment technologies (Judd and Judd, 2011).

Table 1: Reported payback period in previous studies

Study	***Treatment system***	***Location***	***Payback period (years)***
Surendran and Wheatley, 1998	Septic tank-Aerated Bioreactor-Slow sand filter	United Kingdom	8-9 (old bldg.) 4-5 (new bldg.)
March et al., 2004	Filtration- sedimentation-disinfection	Spain	14
Friedler and Hadari, 2006	Rotating Biological Contactors	Israel	6.4-15
Godfrey et al., 2009	Filtration- sedimentation-aeration-disinfection	India	2
Mourad et al., 2011	Constructed wetland	Syria	3-7
Couto et al., 2015	Fixed bed reactor-UV	Brazil	5

In this study, we explore the potential of graywater reclamation in urban areas to contribute to the alleviation of water shortages. For this purpose, the public perception of graywater reuse is assessed using a field questionnaire developed and adminstered at a pilot area. The collected data is analyzed stastically through binomial regression to identify patterns and factors that affect the approval and adoption of graywater reclamation. Additionally, the economic viability of implementing graywater reuse for toilet flushing at a typical apartment in the study area is assessed.

CHAPTER 2
METHODS

2.1 Data Collection and Statistical Analysis

The focus of this study was on graywater reuse and people's openness towards adopting such a technology at the building or community scale in an urban setting. This was evaluated through a questionnaire (Appendix 1), which covered socioeconomics, current sources of water in the study area, quality and consumption patterns of supplied water, public perception of rainwater collection and graywater reclamation systems, and participants' willingness to implement such technologies.

The survey was conducted through personal interviews during household visits, on a one-household-per-building basis, with the surveyed buildings chosen randomly and scattered throughout the study area. The sample size included 103 respondents, representing approximately 0.4% of the total population. Statistical analysis was used to study the factors influencing the acceptance of graywater reuse and the willingness to implement; this was conducted through the development of logistic regression, using the R statistical software. Logistic regression is used when the predicted variable is binary in nature (0 or 1). If Y is the binary predicted variable, then the conditional probability of Y ocuring given a set of predictor variables X is given by p=Prob(Y=1|X). The logit transformation of p $\left(logit = log\left(\frac{p}{1-p}\right)\right)$ is modeled as a linear function of the predictor varaibles (Equation 1).

$$\ln\frac{p}{1-p} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots \beta_i X_i \qquad (1)$$

Where X_i are the predictors, β_0 is the intercept, and β_i are the coefficients. Three response variables were tested: (1) acceptance of graywater reuse; (2) willingness to implement graywater reclamation at the building and (3) willingness to implement at the community level of an urban setting. The first statistical model predicts the acceptance of graywater reuse within the surveyed sample. All predictors were tested by computing the statistical significance at 10% level. After determining the parameters that were individually influencing the variables of interest, stepwise regression was used to determine the optimal combination of parameters based on the Akaike Information Criterion (AIC). The odds ratio[1] of each model's components are calculated and discussed. The pseudo-R^2 value was used to better understand the percentage of data variability explained by the model. Finally, factors with management implications were discussed to extract a set of recommendations for decision-makers based on the statistical results.

2.2 Graywater System Design Considerations

Implementing any graywater reuse system requires mitigating health and environmental risks (Figure 1). Upgrading existing buildings and apartments for graywater separation, collection, treatment, and reuse requires retrofitting existing infrastructure. Experienced plumbers are needed to limit the risk of graywater leakage or infiltration into potable water sources.

[1] The odds ratio of a predictor is a factor that explains the change in the probability of Y being 1 when the predictor's value increases by a single unit. It is determined for each predictor by computing the exponential of its coefficient βi.

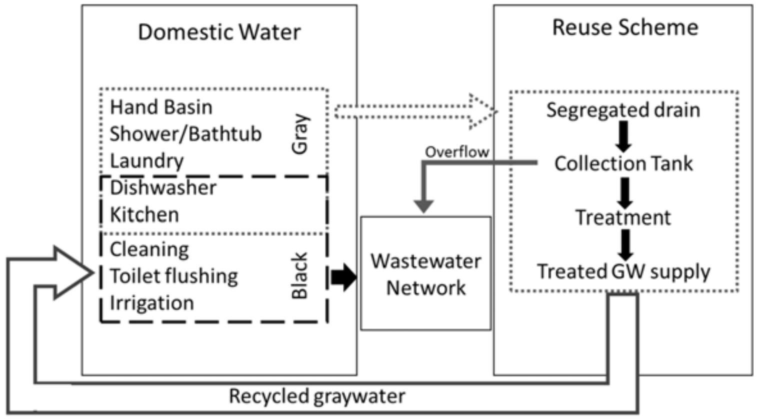
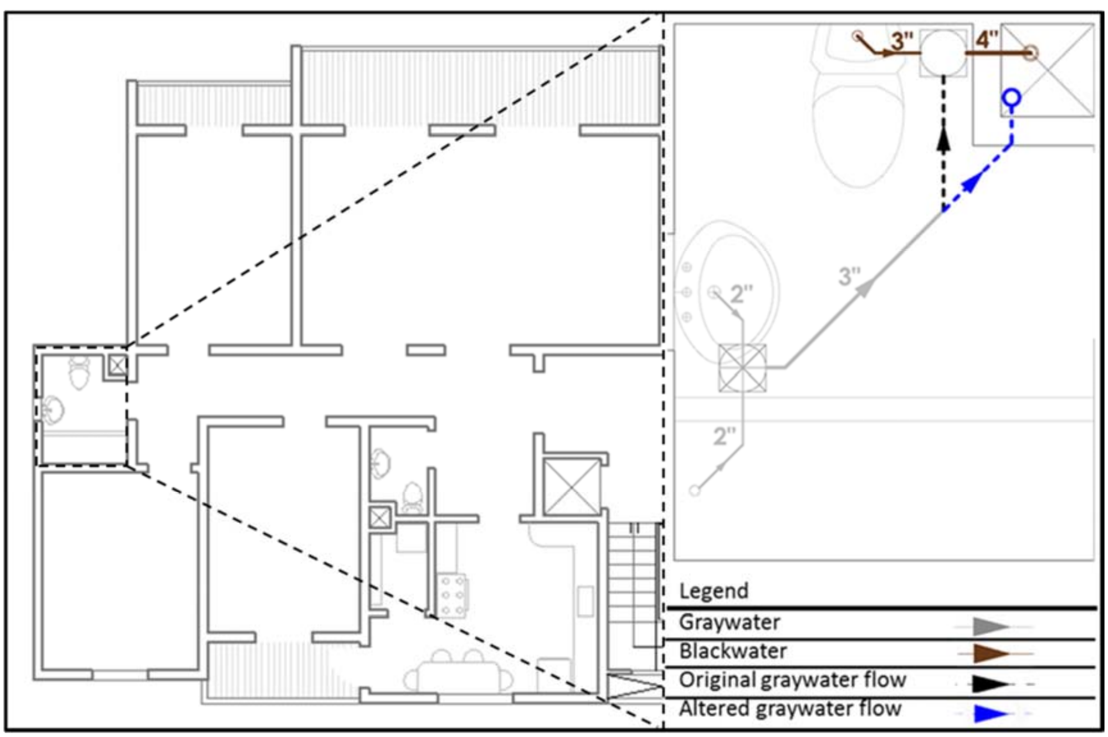


Figure 1: Proposed graywater reuse scheme

A typical apartment's plan was considered in this analysis to estimate the needs and costs of implementation (Figure 2a). Standard retrofitting schemes consist of separating the drainage of washing basins, bathtubs and laundry from the original household water drainage and treating the resulting graywater for toilet flushing, after installing the necessary supply pipes (Figure 2b).



(a) Plan (b) bathroom retrofit

Figure 2: Typical apartment plan for graywater segregation

2.3 Economic Analysis

The cost of implementing graywater reuse can be divided into two parts: the retrofitting and the treatment system cost. The latter could also be divided into capital (procurement and installation) and operating and maintenance expenses. The retrofitting costs were estimated for a typical sized apartment for an average family of 4 individuals. An AutoCAD drawing of the adopted typical apartment plan was developed with the desired specifications, and the corresponding plumbing lines. Retrofitted dual-plumbing needed for the separation of graywater from blackwater and the supply of reuse water to toilets was also generated (Figure 2b). The approximate cost of materials and labor required to complete the retrofitting scheme was calculated after consulting two experienced plumbers based in different locations. Plumbing execution maps were assumed to be available, therefore demolition and reconstruction works were limited to the points of plumbing alterations (not overall renovation of WCs). Moreover, identical tiles to replace the demolished ones were assumed available in the local market. Furthermore, all vertical plumbing connections were presumed accessible through the shafts. We realize that such ideal conditions are not guaranteed (particularly at old buildings with no shafts), thus additional costs could be incurred, and the costs estimated in this study could be considered as average rather than conservative expenses for implementing graywater reuse for toilet flushing at an existing building in the study area.

With respect to graywater treatment, commercial treatment systems available in foreign markets were first surveyed. Local market were also checked for available treatment systems and it was observed that a limited number of local suppliers exists. Nonetheless, the specifications and costs of a single onsite wastewater treatment system available locally were successfully acquired. The resulting list and characteristics of the surveyed treatment systems are attached in Appendix 5.

Finally, to assess the cost-effectiveness of graywater reclamation at the building level in the study area, the full implementation costs were compared to the local cost of potentially saved water volumes, and a payback period was estimated using the net present value (NPV) concept (Equation 2).

$$NPV_T = \sum_t^T \frac{C_T}{(1+i)^t} - C_0 \qquad (2)$$

Where C_T is the net savings per year, C_0 the capital cost, and *i* the inflation rate. Investment is returned when NPV>0.

2.4 SWOT Analysis and Management Framework

A SWOT analysis was conducted to categorize the internal factors (in terms of strengths and weaknesses) and the external factors (in terms of opportunities and threats) that potentially determine the viability of graywater reuse in urban setups and help devise management strategies to improve the chances of successful implementation. The study concludes with a proposed management framework that increases the viability of graywater reuse to improve urban water efficiency while ensuring correct and safe implementation. The framework includes amending/enacting a set of legislations, conducting awareness and capacity building campaigns, and establishing a monitoring and control scheme.

2.5 Study Area

The study area comprises Hazmieh, Hadath and Baabda, three rapidly urbanizing districts located southeast of Beirut, Lebanon (Figure 3), and receiving water from the Greater Beirut and Mount Lebanon Water Establishment. The water tariff structure mostly consists of a traditional yearly lump sum fee that is independent of total water delivered or consumed.

Typically, water is supplied through an old and leaky distribution network leading to a staggering 40 to 50% of water loss (MoEW, 2012). Such losses, when coupled with limited availability, lead to intermittent supplies all year round, even during the rainy season. In fact, water rationing in the dry season increases to a point where a large portion of the population resorts to purchasing of water (i.e. water tankers) to meet daily needs. Water purchase created locally unregulated economies making the delivery of water through water tankers a profitable business, and making water an expensive commodity for urban dwellers. Additionally, the source of water used by water tankers is usually unknown and is often thought to be of inferior quality.

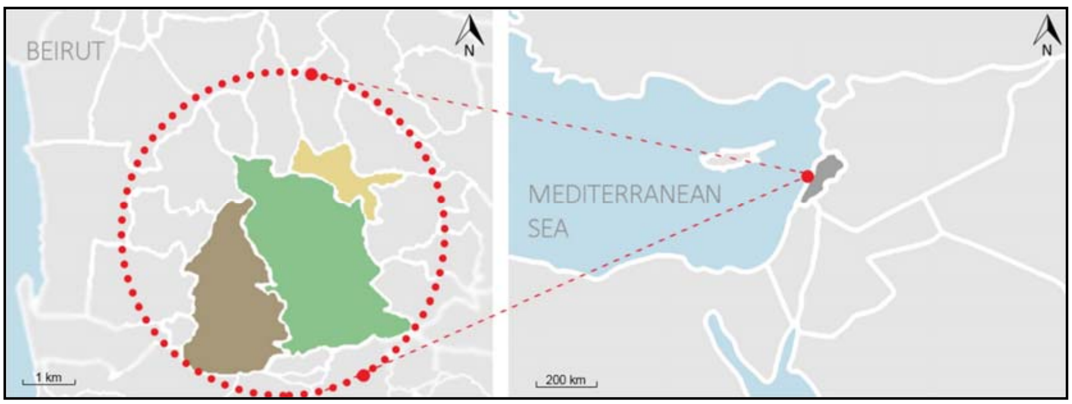


Figure 3: Location of the study area
Hadath (brown), Baabda (green) and Hazmieh (yellow)

A cheaper and more abundant source of water is through groundwater wells, but unsustainable practices led to chronic seawater intrusion problems along coastal cities, particularly Beirut. To add to this complexity, seepage of wastewater into artesian wells has been detected at some locations, raising health concerns for residents relying on those water sources. In Hadath, the poor performance of the public network led to the emergence of another network owned and managed by the municipality. A large portion of Hadath residents have opted to subscribe to that network instead, or in addition to their subscription to the public network. Moreover, other Hadath residents in a newly emerging residential district that is not yet connected to any water network rely solely on artesian wells that provide low-quality water in most cases.

According to many, the Lebanese government is held accountable for these water issues, and is often demanded to exploit more surface water sources to provide a continuous supply of good-quality water, thus averting the need to resort to other sources, particularly the deteriorating groundwater.

CHAPTER 3
RESULTS AND DISCUSSION

3.1 Characteristics of the Study Area

A summary of buildings' characteristics is presented in Table 2 while additional statistics about approval rates and willingness to implement are depicted in Figure 4. The median values for the number of floors (4) and roof area (300 m^2) were adopted for the retrofit case study, while other characteristics such as the annual water bill (average: 186.7 USD) and rate of reliance on water tankers (49%) were considered in the economic analysis.

Table 2: Study area characteristics

Characteristic	*Mean*	*Median*	*Standard deviation*
Number of floors	4.6	4	1.3
Age of Building (years)	34.4	35	20.4
Roof area (m^2)	338.6	300	121.4
Annual water bill (USD) per household	186.7	188.8	57.2
Number of days water is supplied in the dry season	2.2	2	1.2
Hours of supply on water provision days of the dry season	5.3	4	5.7
Number of storage tanks per household	2	2	0.6
Volume of main storage tank (m^3)	9.3	2	16.6
Age of household head	57	60	15.4

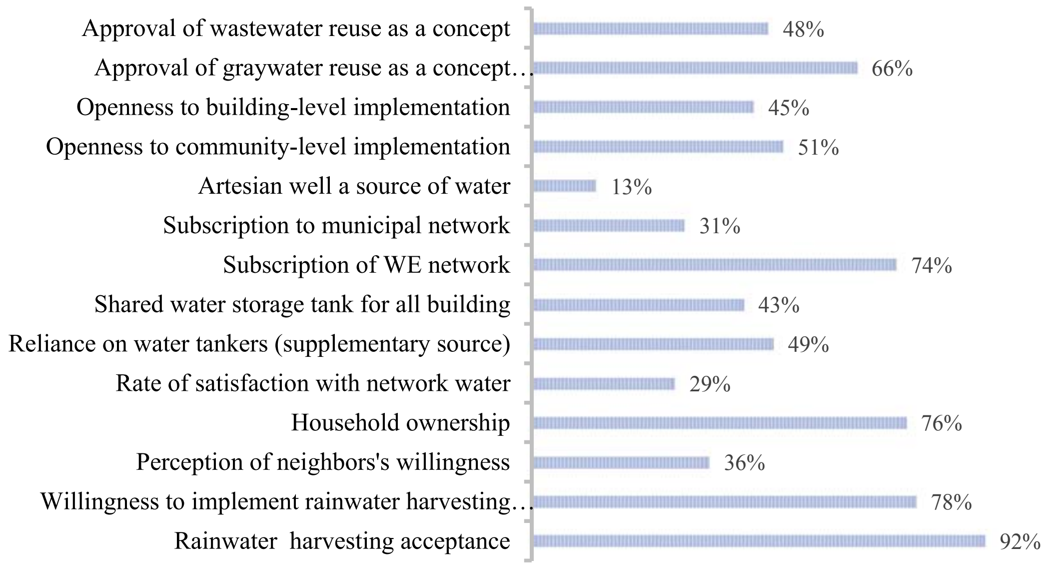


Figure 4: Socio-economic and water-related parameters in the study area

3.2 Statistical Analysis

The three surveyed areas exhibited similar results with no noticeable differences. Approval rates varied between graywater acceptances as a concept to actual implementation (willingness to implement) at the building or community level (Figure 4).

3.2.1 Graywater acceptance

Different potential exploratory variables were tested (Table 3). People's acceptance of rainwater harvesting influenced their acceptance of graywater reclamation positively. This is expected as both techniques provide new water sources and are both considered to be green initiatives. Household ownership was also found to be a factor affecting people's acceptance positively. Moreover, residents who previously renewed their apartment's piping expressed increased acceptance to graywater reuse. Finally, the presence of an artesian well supplying the household provides a sense of water security, which could explain its negative influence on peoples' openness to resort to other sources such as reused water. After performing a stepwise regression, the final model incorporated three variables as significant predictors for graywater acceptance (Table 4).

Table 3: Parameters affecting the acceptance of graywater reuse
Statistical significance was assumed when p-value <0.1 (N=103)

Factor	*Type*	*Influence*	*P value (largest)[a]*
Acceptance of rainwater harvesting	Categorical	Those who accepted rainwater harvesting are more likely to accept graywater reuse	0.097
Household ownership	Categorical	Owning the household increases the chances of accepting graywater reuse, as compared to rental	0.048
Subscription to the public water network	Categorical	Those who are subscribed to the water establishment network are less likely to accept reusing graywater	0.061
Whether apartment's water piping were renewed	Categorical	Those who previously renewed the water connection in their household are more likely to accept the reuse of graywater	0.092
Number of times water is supplied per week in winter	Continuous	The increasing supply of water increases the chances that subscribers accept reusing graywater	0.068
Whether an artesian well is a source of water for the household	Categorical	When the household is provided by water from an artesian well, residents are less likely to accept the reuse of graywater	0.032

[a] *The largest p-value obtained among all categories of the factor.*
[b] *Other sources include the municipality network in Hadath, and a private artesian well.*
[c] *Water is provided on a limited number of days per week due to water rationing policies.*

Table 4: Results of the model that predicts graywater acceptance (N=103)

Variable	*Odds ratio [a]*	*90% conf. int. for odds ratio [b]*	*P value*
Intercept	2.544	1.525-4.403	0.004
Rejecting rainwater harvesting	0.180	0.079-0.582	0.079
Renting the household	0.221	0.032-0.884	0.012
Number of times municipal water is supplied per week in winter	1.449	1.144-1.896	0.015

[a] *The effect of the variable on the chance of accepting graywater reuse.*
[b] *The range of the odds ratio within a 90% confidence.*

The logistic regression model suggests that graywater acceptance is affected significantly by rainwater harvesting acceptance, ownership of dwelling and supply frequency of water in winter. The intercept's odds ratio suggests that there is a 2.54 to 1 (72%) chance of accepting graywater reuse by an individual that has a favorable view of rainwater harvesting, owns the dwelling, and has a twice per week water supply frequency in winter. Meanwhile, those who accept rainwater harvesting are 5.5 times (1/0.18) more likely to accept graywater reuse compared to those that disapprove rainwater harvesting. Moreover, compared to rental, household ownership increases the odds of accepting graywater reuse by 4.5 times (1/0.22). Finally for every day increase in the frequency of water supply in the winter, the respondents' odds of accepting graywater reuse increases by 45%. The maximum computed pseudo-R^2 for this logistic model obtained through Cragg and Uhler's method is 0.406, meaning that the model explains about 41% of the variability in the data.

Table 5: Pseudo-R^2 results of all logistic models of this study (Population 1)

Model	***McFadden's method***	***Maximum likelihood method***	***Cragg and Uhler's method***
Graywater acceptance	0.255	0.312	0.406
Building-level implementation	0.458	0.636	0.715
Community-level implementation	0.401	0.434	0.573

3.2.2 Building-level implementation

After building a model that predicted graywater reuse acceptance, a similar attempt was made to predict the willingness to implement it at the building and community level using two different approaches for the choice of population. The first approach (population 1, N=64) presumed that those who had an unfavorable view for the concept of reusing graywater would not answer positively to the possibility of sharing a graywater reuse system, so the population chosen in this case was limited to respondents who had a favorable view of graywater reuse. On the other hand, the second approach (population 2, N=103) assumed that the respondent's negative opinion on graywater reuse did not necessarily lead to their refusal of being involved in a future graywater reuse scheme when potential water/financial savings are foreseen, so the same population of the first case was adopted. In what follows, the results and discussion will be limited to population 1 while the results of population 2 are detailed in Appendix 2.

As a result of the binary logistic tests, 4 significant predictors were determined when testing on population 1 (Table 6), and 7 for the case of population 2 (Appendix 2). The common predictors were the annual water bill, number of storage tanks and the perception of building neighbors' willingness to implement graywater reuse.

Table 6: Factors affecting the willingness to implement graywater reuse at the building level
Statistical significance was assumed when p-value <0.1 (N= 64)

Factor	***Type***	***Influence***	***P value (largest)***
Annual bill to water authority [a]	Continuous	A larger yearly bill decreases the chance of adopting graywater reuse at the building level	0.024
Volume of main storage tank	Continuous	The smaller the tank is, the more likely for a household to implement	0.077
Number of water storage tanks [b]	Continuous	The larger the number of storage tanks for a household, the less likely for it to adopt the reuse of graywater	0.096
Perception of building residents' willingness to implement graywater reuse at their building	Categorical	Those believing that their building neighbors would support the adoption of graywater reuse are more likely to adopt it themselves	0.032

[a] *Annual water bill depended on location and network(s) subscribed to. Values ranged between 100 and 400 USD, with a median of 190 USD.*
[b] *The number of storage tanks per household ranged from 1 to 4, with a median of 2.*

According to the results, larger yearly water bills decrease the chance of adopting graywater reuse at the building level, which indicates that respondents saw the technology as a financial burden more than a chance to save on water consumption. Moreover, the likelihood of adopting the technology was reduced when the number or volume of household storage tanks increased; this indicates that the ability to store a large quantity of water reduces the chances of facing water shortages. Finally, the environment in which the respondents reside also affected their willingness to adopt graywater reuse at the building-scale; residents were more likely to adopt it when they believed that their building neighbors would agree to contribute to such a plan. The final model explaining the willingness to implement graywater reuse at the building level is shown in Table 7.

Table 7: Model for predicting the willingness to implement graywater reuse at the building level

Variable	*Odds ratio*	*90% conf. int. for odds ratio*	*P value*
Intercept	4.000	1.510-13.355	0.032
Building residents' are thought to be unwilling to implement graywater reuse at their building	0.166	0.041-0.574	0.023

The derived model included one significant predictor that is the perception of building-neighbors' openness to participate in a graywater reuse plan at the building-scale. According to the model, when respondents believe that the neighbors would welcome the implementation of a graywater reuse plan at their building, the chances of adopting graywater reuse at the building level are 4 to 1, and is approximately 6 times (1/0/166) more likely when compared to a situation where the building neighbors are not perceived to be willing to adopt the technology. Note that the model received a maximum pseudo-R^2 of 0.715 (Table 5), implying that 71.5% of the variability in the data is explained by the logit model.

3.2.3 Community-level implementation

For this case, three significant predictors were determined for population 1 (Table 8) and six for the case of population 2 (Appendix 2). Two of the common ones were the approval to participate in both a rainwater harvesting plan at the community level and a graywater reuse plan at the building level. Expectedly, the approval to participate in the two plans increases the likelihood of participating in a graywater reuse plan at the community level. The last common predictor was the age of household head, with younger respondents displaying more openness towards the adoption of a community level graywater reclamation system as compared to older individuals. This is an interesting outcome, which could imply that the younger population is more aware of scientific advances, and is thus more receptive to relatively-modern technologies for the reduction of water consumption.

Table 8: Factors affecting the willingness to implement graywater reuse at the community level
Statistical significance was assumed when p-value <0.1 (N= 64)

Factor	*Type*	*Influence*	*P value (largest)*
Approval to participate in a municipal rainwater harvesting plan	Categorical	The approval to participate in a municipal rainwater harvesting plan expectedly increases the likelihood of adopting a similar graywater reuse plan	0.008
Year of birth for the household head	Continuous	Younger people are more likely to adopt graywater reuse at the community level	0.094
Approval to implement graywater reuse plan at the building level	Categorical	Approval of adopting graywater at the building level also increases the odds of it being adopted at the community level	0.020

After determining the individually influential parameters, a stepwise regression was conducted, where the optimal combination of parameters was determined. The resulting model that predicts the willingness to implement graywater reuse at the community level incorporated the variables listed in Table 9. Two significant predictors were incorporated into the model that predicts the willingness to implement graywater reclamation at the community level: the approval to participate in a rainwater harvesting plan at the community level and the willingness to implement graywater reuse plan at the building level. Under a baseline condition consisting of approving both plans, the odds of implementing a graywater reclamation at the community level are 10.4 to 1. Meanwhile, as compared to refusing it, the willingness to implement rainwater harvesting at the community level increases the chance of adopting community-level graywater reuse by

67 times (1/0.015). The willingness to implement graywater reuse at the building level has a similar effect as it increases by approximately 13 times (1/0.078) the chance of adopting graywater reuse at the community level.

The model earned a maximum pseudo-R^2 of 0.573 (Table 5), indicating that it explains 57.3% of the variability in the data. The value is remarkably lower than the first model that predicted the willingness to implement graywater reuse at the building level, despite having two significant predictors.

Table 9: Model predicting the willingness to implement graywater reuse at the community level

Variable	*Odds ratio*	*90% conf. int. for odds ratio*	*P value*
Intercept	10.40	3.636-45.48	0.002
Disapproval of participating in a municipal rainwater harvesting plan	0.015	0.001-0.089	0.001
Disapproval of graywater reuse at building level	0.078	0.015-0.281	0.003

In closure, the statistical analysis aimed to identify the parameters that influence the acceptability of graywater reuse and the willingness to implement it at both the building and community levels. A set of predictors were derived, some of which were anticipated due to the direct causal relationship with the predicted variables such as the influence of graywater reuse acceptance on the willingness to implement at the building or community level.

On the other hand, some other predictors gave a different perspective on what affects the public's response to the technology of graywater reuse and would be useful when devising a management approach for the large-scale implementation of graywater reuse. The relevant parameters are summarized in Table 10.

Table 10: Relevant parameters affecting the public's response to graywater reuse and management implications

Parameter	***Influence***	***Implication***
Owning the household	Positive	Areas where the rate of ownership is high are better targets for the consideration of implementing a graywater reclamation project.
Annual water bill	Negative	The introduction of volumetric water tariffs would create an incentive for water conservation measures at the consumer level with potential savings on the water bill. Awareness campaigns about potential benefits of water saving measures for the purpose of altering the perception of it being just an additional financial burden.
Having an artesian well as a source of water for the household	Negative	Enactment of stricter laws preventing any exploitation of groundwater for the double benefit of increasing the likelihood of adopting water saving measures such as graywater reuse as well as protecting groundwater sources from saltwater intrusion
Number of storage tanks	Negative	Building code should limit the number or the volume of household storage tanks, thus driving consumers to spare water use as their reserves become limited
Age of the head of household	Negative	The younger generation seems to be more receptive to modern water saving techniques such as graywater reuse which presents a positive sign with respect to the future prospect of large-scale implementation of graywater reuse

3.3 Economic Analysis

To assess the cost-effectiveness of adopting graywater reuse at the building level in the study area, the saved water cost needs to be compared to the capital and operating costs of the building-level implementation. The total estimated capital costs for the implementation of the system for the whole building, including retrofitting ($5,300) and treatment system costs, are 10,300 USD, or 1,300 USD per household (10,300/8). Meanwhile, the volumetric water charge in the study area is 0.43 USD/m^3 and the daily water consumption per capita is estimated at 180 liters (MoEW, 2012). Assuming 4 individuals per household (from the survey), the estimated yearly consumption would be 263 m^3. Meanwhile, the adoption of graywater reuse for toilet flushing is expected to save 79 m^3 (30%) of household consumption. At the current rate, the yearly savings per household would amount to around $34, meaning that the payback period for the retrofitting costs alone would exceed 30 years.

However, considering the water rationing policy in the study area, a large portion of the population relies on water tankers in the dry season, as a supplementary water source (about 49% of surveyed households); if the scenario accounts for money spent on water tankers, then the payback period becomes considerably shorter since the median monthly expenditure on water tankers according to the survey results is 147 USD. Assuming the water shortage occurs for 3 or 4 months in the dry season of every year, the resulting yearly water tanker expenses per household would be 440 or 586 USD, respectively. If 30% of that is also saved by adopting graywater reuse, and added to original metered water savings, then the total implementation costs are compensated within 9-12 years of adopting graywater reuse at an inflation rate of 5% (Figure 5).

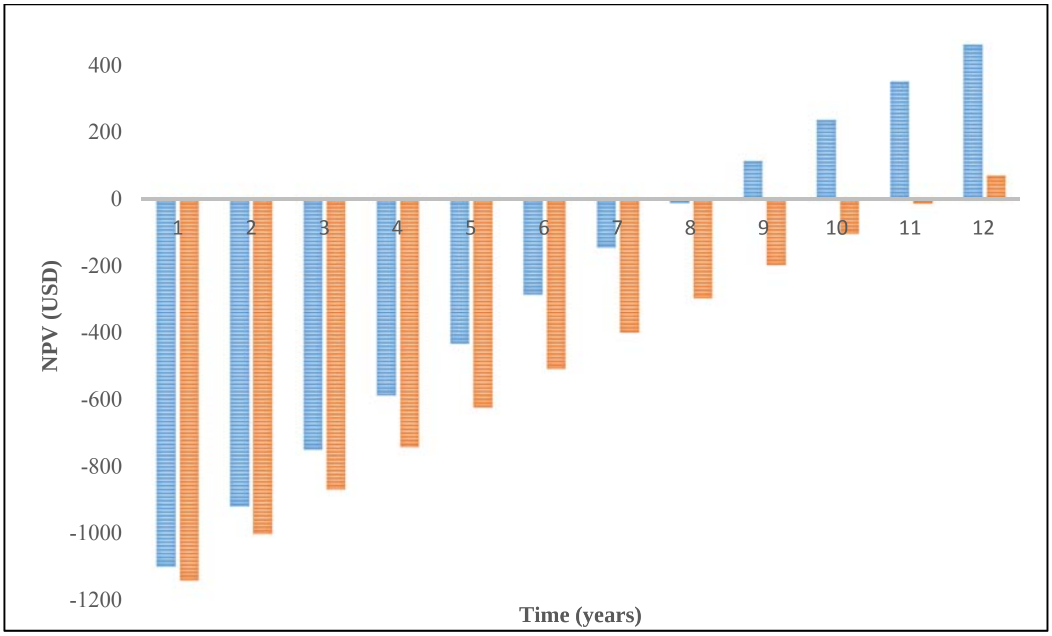


Figure 5: Cumulative NPV if water tankers are needed for 3 months (orange) and 4 months (blue)

The current water tariff structure in the study area is acknowledged by the governing authorities as far from ideal; the largest portion of subscribers pay a flat lump sum tariff irrespective of actual consumption, due to the absence of water meters, and there remains no wastewater tariffs to date (MoEW, 2012). Therefore the installation of meters for all subscribers would be an essential first step that provides more accurate insight into water consumption patterns and help devise a convenient water tariff structure that maintains affordability while promoting water conservation and reuse. In the same context, the establishment of a wastewater tariff would also deliver an added incentive to increase the feasibility of adopting graywater reuse.

3.4 SWOT Analysis

The SWOT analysis aimed at categorizing the internal and external factors affecting graywater reuse implementation to help illustrate positive features and the negative aspects to address when devising a management plan for graywater reuse implementation in urban setups.

In terms of strengths, graywater is a year-round source of water that can be reused to reduce the stress on freshwater resources and water authorities by decreasing demand, and establishing a decentralized water reuse scheme that requires minimal institutional involvement.

On the other hand, the existing plumbing code does not require separating graywater from blackwater drainage, thus a retrofit is needed prior to adopting graywater reuse which entails an initial capital investment in addition to the cost of the treatment system. Moreover, some governmental resources will need to be allocated to monitor and ensure safe implementation of graywater reuse.

In terms of opportunities, the recurring drought events in recent years have increased the openness to wastewater reuse for the purpose of decreasing both water demand and volumes of wastewater that are considered a burden in many developing countries. Additionally, the acceptable payback periods of graywater systems reaching below 10 years can further be reduced in future cases after the integration of dual plumbing within the building code by eliminating the cost of retrofit which constituted about 50% of the capital costs in our case study.

As for the factors potentially threatening the success of graywater reuse, one cannot overlook the risk of mismanagement by individual users and the risk of cross-contamination between graywater and potable connections, in addition to the negligence of treatment systems which require frequent inspection to maintain treatment efficiency. In this context, the current lack of local standards for the quality of treated water intended for domestic reuse should also be addressed by the responsible authorities to minimize any potential health risks. Table 11 summarizes the strengths, weaknesses, opportunities and threats associated with the adoption of graywater reuse, particularly in the local context.

Table 11: SWOT Analysis

Strengths	***Weaknesses***
• Reliable all-year-round source of water • Treating graywater for reuse in landscape irrigation and toilet flushing reduces stress on freshwater sources • Adopting a decentralized reuse scheme with minimal institutional involvement • Unsophisticated technology that can be managed by its users • Reduce demand and thus governmental expenses on exploiting additional, and often costly, water sources • Promoting the importance of water conservation	• Traditional plumbing does not separate graywater from blackwater drainage • Retrofit is often expensive and inconvenient • Additional capital costs required to install a treatment system • Lack of public knowledge about the importance of water conservation and scarcity of resources • Would still require the allocation of some government resources to monitor implementation
Opportunities	***Threats***
• Local governments are more open to wastewater reuse following the recurrence of drought events • Reduction of demand reduces need for supplementary sources such as the over-exploited groundwater, and thus decreases the extent of saltwater intrusion • Return on investment could be achieved in less than 10 years in some cases • Future feasibility of adopting graywater reuse would significantly increase if graywater segregation is integrated in the plumbing code, thus eliminating the cost of retrofit (around 50% of the capital cost in this case study) • Installation of water meters and enactment of volumetric water charges present an additional incentive • Awareness/educational campaigns about water scarcity and potential efficiency of wastewater reuse can significantly improve acceptance rates	• General public skepticism about wastewater reuse and efficiency of treatment technologies • Risk of mismanagement and use for unintended purposes • Potential health risks in case of cross-contamination between graywater and potable water networks • Requires regular maintenance to ensure treatment efficiency • Current lack of local regulations/ standards for quality of water intended for domestic reuse.

3.5 Management Framework

Similar to many developing countries, the water sector in the pilot area faces multiple issues. Up to 50% of supplied water is lost through the outdated and leaky public distribution network leading to extensive water shortages and in turn, forced rationing policies. A set of alternative options are exploited including artesian wells and private water tankers. These alternatives are mostly unregulated leading to a multitude of concerns including water quality and overexploitation which triggered saltwater intrusion. Furthermore, surface water pollution has considerably affected the water quality of tankers. In light of this, many have opted to install expensive desalination systems to treat the salty water from private artesian wells. However, while this reduces water deficit for individual cases, it greatly exacerbates the extent of saltwater intrusion into freshwater aquifers. Thus, governmental involvement is needed to control, regulate, and encourage alternative and sustainable options for reducing the existing deficit. In this context, graywater reuse can provide significant year-round quantities for particular non-potable uses. However, it is imperative to have the necessary regulations and standards in place to control the propagation of this technology and ensure its success.

Furthermore, graywater reuse should be adopted as part of a set of alternative water sources constituting a sustainable water management framework. This becomes most effective if a policy controlling the exploitation of vulnerable sources, particularly groundwater, through a gradual decrease of its use can be enforced to regulate the supply and entice residents to adopt the use of alternative water sources. Several institutions would take part in the development and implementation of such a management framework. The roles of those institutions are presented in Table 12. For example, the legislative bodies are required to set up the necessary regulations after reviewing international legislations and conducting necessary research. Subsequently, the local authorities would be responsible to ensure compliance with proposed regulations through direct contact with consumers. In parallel, media and civil society would play a major role through awareness campaigns about water scarcity and efficient water management techniques such as graywater reuse to increase public recognition and acceptance of reuse systems.

When approaching the issue of adopting graywater reuse at the governance level, the implementation at an existing building can be differentiated from that at a new building under construction. As previously discussed, the adoption of graywater reuse prior to the completion of a building would be more feasible since the cost of retrofit is eliminated. In that case the decision making required would be limited to some modifications to the building code, requiring the compulsory adoption of dual plumbing. On the other hand, guidelines can be released for the retrofit of existing buildings, and incentives to adopt the technology can be established such as tax reduction or exemption.

Table 12: Institutional framework for graywater reuse

Institution	***Responsibilities***
Water Establishment	• Complete the implementation of water metering (currently at 10%) • Set up an increasing block tariff structure (MoEW, 2012) for water supply to encourage conservative usage • Monitor the implementation of graywater reuse • Collect taxes and penalize illegal activities such as using graywater for unintended purposes • Prevent further groundwater exploitation and start decommissioning illegal wells
Ministry of Energy and Water	• Establish water rights for building/community implementation (Permit procedure for graywater reuse) • Fund a set of pilot graywater reuse projects at various locations and for different applications, and report the successes and failures • Provide subsidies for graywater reuse implementation in the form of low interest loans • Tax exemptions on procurement of treatment systems (new and old buildings) • Tax cuts on graywater treatment consumables and graywater -friendly household chemicals • Gradually increase taxations on discharged wastewater volumes
Ministry of Interior and Municipalities	• Establish municipal tax exemptions to graywater reuse adopters • Study the potential for community-level graywater reuse projects
Ministry of Public Health	• Establish quality standards for graywater reuse that minimize potential health risks while maintaining feasibility
Order of Engineers	• Modify building codes to include mandatory segregation of graywater from blackwater • Release retrofit guidelines for graywater reuse implementation (old buildings) • Release guidelines for graywater reuse including dual water supply lines, best management practices, and applicable treatment systems and associated end-uses of treated graywater.
Civil Society	• Awareness campaigns about the scarcity and vulnerability of freshwater sources, particularly the deteriorating groundwater due to overexploitation • Introduce the public to the concept of graywater (vs. blackwater) as a reliable year-round alternative water source, and its applications depending on treatment level • Inform the public about tax exemptions and benefits associated with graywater reuse and the existing guidelines for implementations at new and old buildings • Highlight the importance of using graywater-friendly chemicals to ensure efficient treatment and prevent damage to soil (in the case of irrigation)
Media	• Advertisement campaigns about water scarcity and needed conservation measures, graywater reuse and associated benefits in terms of tax cuts and exemptions. • Public awareness to best management practices to ensure safe and hygienic graywater reuse

The proposed management framework (Table 13) for improved graywater reuse targets a change in water consumptive behaviors in terms of perception and quantities. As such, the water consumer is placed as its center point with four agents of change around: awareness, incentives, legislations, and taxations. Institutions have roles to play in each of the different agents and their contributions are color coded within the proposed management framework.

Table 13: Management framework for graywater reuse

Awareness	***Incentives***
• Graywater reuse pilot projects (highlight success stories). • Fund and conduct research to propose adequate quality standards for reused graywater	• Tax exemptions on treatment system procurement (new and old buildings) • Tax cuts on GW treatment consumables and GW-friendly household chemicals
• Scarcity/vulnerability of resources (Freshwater/saltwater intrusion) • Black vs. graywater • Introduce public to graywater separation guidelines for new and old buildings, and to tax exemption benefits • Graywater-friendly chemicals	• Soft loan structure for retrofit procedure (old buildings) and for treatment system procurement (new and old buildings) • Municipal tax reduction for GW reuse adopters
Consumer Demand / Behavior	
Legislations	***Taxations***
• Establish water rights for building/community implementation (Permit procedure for graywater reuse)	• Gradually increase taxations on discharged wastewater volumes
• Modify building codes to include mandatory segregation of graywater from blackwater • Release retrofit and guidelines for graywater reuse implementation (old buildings)	• Fully implement Water-metering plans • Monitor the implementation of graywater reuse • Collection of taxes and penalizing illegal activities (use of graywater for unintended purposes, illegal groundwater pumping, etc...)
• Prevent further groundwater exploitation and start decommissioning illegal wells	

Legend (responsible party)

- *Legislators*
- *Water Establishment*
- *Government / Municipalities*
- *Media/civil society*
- *Order of Engineers*

CHAPTER 4
CONCLUSION AND RECOMMENDATIONS

Graywater reuse is a viable option to reduce potable water demand in urban communities suffering from chronic water shortages associated with increased population growth, development, and urbanization exacerbated with potential climate change impacts. Reduction in demand would decrease the need for complementary sources such as groundwater, the exploitation of which has been inducing saltwater intrusion in many coastal regions. Reusing graywater for large-scale landscape irrigation would have further mitigating impacts through indirect groundwater recharge. Another potential end-use is toilet flushing which can decrease domestic water demand by 30%, as well as reduce the generation of wastewater that remains an environmental concern when untreated, particularly in developing countries.

An objective of this study was to explore the factors that affected the acceptability of graywater reuse through logistic regression. The statistical analysis identified some patterns that need to be considered when devising a future water reuse management plan at a community level. A building level implementation was also considered that addressed retrofitting design and treatment system installation. A subsequent economic analysis concluded that graywater reuse may not be economically attractive under the current water tariff structure in the pilot area, apart from certain areas where private water tankers are frequently needed in the dry season.

Generally, the main approach to solve water scarcity in the study area has been to explore more surface water resources. In fact, a plan is in place to construct a large river dam for this purpose in the near future. However, instead of focusing on increasing supply, resources could be invested into reducing water demand. For instance, reducing the 40-50% losses in the public network of the pilot area should be a top priority, therefore leakages should be located and repaired to improve distribution efficiency and thus decrease the extent of water rationing currently in place. Moreover, subsidies could be put in place to promote water-efficient devices, particularly for household use, and promote water saving measures such as rainwater harvesting and graywater reuse. And for the latter to become a feasible water resource to exploit in the study area and decrease the reliance on groundwater, the following recommendations need to be considered:

- Current water billing configuration needs to be revised; an increasing block tariff structure is recommended to encourage efficient use of the resource that is inaccurately perceived to be abundant by the general public.
- Installation of water meters for all subscribers; while the National Water Sector Strategy indicated that 10% of subscriptions were metered, the lump sum tariff for the remaining 90% overwhelmingly discourages efficient use of water resources by the majority of subscribers.
- Stricter rules should be implemented to prevent groundwater exploitation particularly by inefficient individual consumers, and the storage of large amounts of water for personal use should be prohibited.
- Launching of awareness campaigns to educate the general public on the importance of water resources, saltwater intrusion, and water-efficient approaches including graywater reuse.

REFERENCES

Abdel-Kader, A.M. (2012). Studying the efficiency of grey water treatment by using rotating biological contactors system. Journal of King Saud University - Engineering Sciences *25*, 89–95.

Abudi, Z.N. (2011). The effect of sand filter characteristics on removal efficiency of organic matter from grey water. Al-Qadisiya Journal for Engineering Sciences *4*, 143–155.

Aeschbach-hertig, W., and Gleeson, T. (2012). Regional strategies for the accelerating global problem of groundwater depletion. Nature Geoscience *5*, 853–861.

Ahmed, M., Sidairi, S.A., Prathapar, S.A., and Al-Adawi, S. (2008). Evaluation of custom-made and commercial greywater treatment systems: a case study from Oman. International Journal of Environmental Studies *65*, 33–40.

Al-Jayyousi, O.R. (2003). Greywater reuse: towards sustainable water management. Desalination *156*, 181–192.

Alqam, M., Jamrah, A., Abd Al-Hafith, B., Al-Zubi, R., and Al-Shamari, N. (2014). Fresh and Hardened Properties of Sustainable Concrete Using Recycled Household Greywater. Arabian Journal for Science and Engineering *39*, 1701–1708.

Asadollahfardi, G., Delnavaz, M., Rashnoiee, V., and Ghonabadi, N. (2016). Use of treated domestic wastewater before chlorination to produce and cure concrete. Construction and Building Materials 105, 253–261.

Ashkar, R. (2015). Personal communication. Telephone call.

Assayed, A., Chenoweth, J., and Pedley, S. (2015). Assessing the efficiency of an innovative method for onsite greywater treatment: Drawer compacted sand filter – A case study in Jordan. Ecological Engineering 81, 525–533.

Barlow, P.M., and Reichard, E.G. (2010). Saltwater intrusion in coastal regions of North America. Hydrogeology Journal *18*, 247–260.

Beek, L.P.H. van, van Kempen, C.M., Reckman, J.W.T.M., and Wada, Y. (2010). Global depletion of groundwater resources. Geophysical Research Letters *37*.

Campisano, A., and Modica, C. (2010). Experimental investigation on water saving by the reuse of washbasin grey water for toilet flushing. Urban Water Journal 17–24.

Chaillou, K., Gérente, C., Andrès, Y., and Wolbert, D. (2011). Bathroom Greywater Characterization and Potential Treatments for Reuse. Water, Air, & Soil Pollution *215*, 31–42.

City of Los Angeles (1992). Graywater pilot project final report (Los Angeles, California: Office of Water Reclamation).

COP (2010). Code of Practice for Reuse of Greywater in Western Australia 2010. (Government of Western Australia, Department of Health).

Couto, E. de A. do, Calijuri, M.L., Assemany, P.P., Santiago, A. da F., and Lopes, L.S. (2015). Greywater treatment in airports using anaerobic filter followed by UV disinfection: an efficient and low cost alternative. Journal of Cleaner Production *106*, 372–379.

El Hamouri, B., Bey, I., Douch, A., Ghazi, N., and Regelsberger, M. (2008). Greywater treatment and recycling for toilet flushing: comparison of low and high tech treatment approaches. Water Practice & Technology *3*, 1–9.

Eliasson, J. (2015). The rising pressure of global water shortages. Nature *517*, 6.

EPA (2012). Guidelines for Water Reuse (Washington, D.C.: U.S. Environmental Protection Agency Office of Wastewater Management).

Eriksson, E., Auffarth, K., Henze, M., and Ledin, A. (2002). Characteristics of grey wastewater. Urban Water *4*, 85–104.

European Commission (2013). Updated report on wastewater reuse in the European Union.

FAO (1993). The State of Food and Agriculture.

Foster, S.S.D., and Chilton, P.J. (2004). Downstream of downtown: urban wastewater as groundwater recharge. Hydrogeology Journal *12*, 115–120.

Friedler, E., and Hadari, M. (2006). Economic feasibility of on-site greywater reuse in multi-storey buildings. Desalination *190*, 221–234.

Friedler, E., Kovalio, R., and Galil, N.I. (2005). On-site greywater treatment and reuse in multi-storey buildings. Water Science & Technology *51*, 187–194.

Friedler, E., Kovalio, R., and Ben-Zvi, A. (2006). Comparative Study of the Microbial Quality of Greywater treated by Three On-Site Treatment Systems. Environmental Technology *27*, 653–663.

Gikas, P., and Tchobanoglous, G. (2009). The role of satellite and decentralized strategies in water resources management. Journal of Environmental Management *90*, 144–152.

Gleick, P.H. (2014). World’s Water, Volume 8 : Biennial Report on Freshwater Resources (Washington, DC, USA: Island Press).

Godfrey, S., Labhasetwar, P., and Wate, S. (2009). Greywater reuse in residential schools in Madhya Pradesh, India—A case study of cost–benefit analysis. Resources, Conservation and Recycling *53*, 287–293.

Groundwater Governance (2015). Global diagnostic on groundwater governance (Groundwater Governance).

Imteaz, M., and Shanableh, A. (2011). Feasibility of Recycling Grey-water in Multi-Storey Buildings in Melbourne. In 2nd World Sustainability Forum,.

Ingman, D., Friedler, E., and Aizenchtadt, E. (2009). Analysis of the long-term performance of an on-site greywater treatment plant using novel statistical approaches. Urban Water Journal *6*, 341–354.

Jokerst, A., Sharvelle, S.E., Hollowed, M.E., and Roesner, L.A. (2011). Seasonal Performance of an Outdoor Constructed Wetland for Graywater Treatment in a Temperate Climate. Water Environment Research *83*, 2187–2198.

Judd, S., Judd, C. (2011). The MBR Book (Second Edition). (Oxford: Butterworth-Heinemann), pp. 1–54.

Kuru, B., and Luettgen, M. (2012). Investigation of Residential Water Reuse Technologies (Las Vegas).

Lattemann, S., and Höpner, T. (2008). Environmental impact and impact assessment of seawater desalination. Desalination *220*, 1–15.

Li, F., Wichmann, K., and Otterpohl, R. (2009). Review of the technological approaches for grey water treatment and reuses. Science of the Total Environment *407*, 3439–3449.

Lu, W., and Leung, A.Y.T. (2003). A preliminary study on potential of developing shower/laundry wastewater reclamation and reuse system. Chemosphere *52*, 1451–1459.

Mahesha, A., and Lakshmikant, P. (2014). Saltwater Intrusion in Coastal Aquifers Subjected to Freshwater Pumping. Journal of Hydrologic Engineering *19*, 448–456.

Mandal, D., Labhasetwar, P., Dhone, S., Dubey, A.S., Shinde, G., and Wate, S. (2011). Water conservation due to greywater treatment and reuse in urban setting with specific context to developing countries. Resources, Conservation and Recycling *55*, 356–361.

March, J.G., Gual, M., and Orozco, F. (2004). Experiences on greywater re-use for toilet flushing in a hotel (Mallorca Island, Spain). Desalination *164*, 241–247.

Massoud, M.A., Tarhini, A., and Nasr, J.A. (2009). Decentralized approaches to wastewater treatment and management: Applicability in developing countries. Journal of Environmental Management *90*, 652–659.

Mayer, P.W., DeOreo, W.B., Opitz, E.M., Kiefer, J.C., Davis, W.Y., Dziegielewski, B., and Nelson, J.O. (1999). Residential end uses of water (Denver, CO: AWWA Research Foundation and American Water Works Association).

Memon, F.A., Zheng, Z., Butler, D., and Shirley-Smith, C. (2007). Life Cycle Impact Assessment of Greywater Recycling Technologies for New Developments. Environmental Monitoring and Assessment *129*, 27–35.

MoEW (2012). National Water Sector strategy (Beirut: Lebanese Government).

Morel, A., and Diener, S. (2006). Grey water management in low and middle-income countries. Water and sanitation in developing countries (Sandec). Eawag, Switzerland: Swiss Federal Institute of Aquatic Science and Technology.

Mourad, K.A., Berndtsson, J.C., and Berndtsson, R. (2011). Potential fresh water saving using greywater in toilet flushing in Syria. Journal of Environmental Management *92*, 2447–2453.

Nolde, E. (1999). Greywater reuse systems for toilet flushing in multi-storey buildings – over ten years experience in Berlin. Urban Water *1*, 275–284.

O'Callaghan, P. (2008). Decentralised Wastewater Management: a solution to infrastructure bottlenecks? Engineers Journal 448–450.

Poorman, L. (2007). Managing water use. eMDE *3*.

Santasmasas, C., Rovira, M., Clarens, F., and Valderrama, C. (2013). Grey water reclamation by decentralized MBR prototype. Resources, Conservation and Recycling 102–107.

Surendran, S., and Wheatley, A.D. (1998). Grey-water reclamation for non-potable re-use. Water and Environment Journal *12*, 406–413.

WHO-ROEM (2006). Overview of graywater management: health considerations (Amman, Jordan: World Health Organization. Regional Office for the Eastern Mediterranean. Centre For Environmental Health Activities).

WHO/UNEP/UN-Habitat (2015). Wastewater Management, A UN-Water Analytical Brief (UN-Water).

Winward, G.P., Avery, L.M., Frazer-Williams, R., and Pidou, M. (2008). A study of the microbial quality of grey water and an evaluation of treatment technologies for reuse. Ecological Engineering *32*, 187–197.

Yu, Z.L.T., DeShazo, J.R., Stenstrom, M.K., and Cohen, Y. (2014). Cost-Benefit Analysis of Onsite Residential Graywater Recycling. Luskin at UCLA.

Zeeman, G., Fayyed, M., Lier, van, and Abu-Ghunmi, L.N.A.H. (2008). Quantitative and qualitative characteristics of grey water for reuse requirements and treatment alternatives: the case of Jordan. Water Science and Technology *58*, 1385–1396.

APPENDIX 1
QUESTIONNAIRE

Effects of saltwater intrusion on domestic water uses in the Hazmieh/Hadath/Baabda Area

Questionnaire Identification					**ID |___|___|-|___|___|-|___|___|**
AI1	**Zone**	|___||___|	AI 5	**Floor no.**	|___|___|
AI2	**Street**	________________________	AI 6	**Housing unit no.**	(Start from right side) |___|
AI3	**Neighbourhood**		AI 7	**GPS coordinates**	N: __________________________________
AI4	**Building**	________________________	AI 8		E: __________________________________

Wellwater Sampling		
WWS1	Do we have access to the first discharge of the artesian well to take sample?	________________________
WWS2	Can we measure the water level in the well? (drop meter to touch water level)?	________________________

Schedule					
AV1	First Visit	DD.MM.YY |___|___|.|___|___|.|___|___|	AT1	Start of interview (time)	hh:mm |___|___|:|___|___|
			AT2	End of Interview (time)	hh:mm |___|___|:|___|___|
AV2	Second Visit	DD.MM.YY |___|___|.|___|___|.|___|___|	AT3	Start of interview	hh:mm |___|___|:|___|___|
			AT4	End of Interview	hh:mm |___|___|:|___|___|

Staff					
AS1	**Interviewer**	|___|___|	AS4	**Coder**	|___|___|
AS2	**Supervisor**	|___|___|	AS5	**Data entry operator**	|___|___|
AS3	**Editor**	|___|___|			

Respondent			
AH1	**Name of household head (optional)** ____		
AH2	**Name of main Respondent (optional)** ____		
AH3	**Gender of Respondent**		
AH4	**Marital status of respondent**		
AR1	**Interview status**		
	1	Interview completed	**COMMENTS :**
	2	Refusal converted	
	3	Partly completed	
	4	No usable information	
	5	Household unit is vacant	
	6	No contact	
	7	Refusal	

Additional comments

____

سوف أبدأ بالسؤال عن المبنى الذي تسكن فيه

	معلومات حول المبنى (Building Information)		
BI1	ما هو عدد الطوابق التي فيها شقق؟	|___|___|	طابق
BI2	ما هو العدد الإجمالي للشقق المسكونة ؟	|___|___|	شقة
BI3	ما هو العدد الإجمالي للشقق الغير مسكونة؟ (تبقى فارغة لأكثر من 3 أشهر)	|___|___|	شقة
BI4	كم عمر المبنى ككلّ؟	|___|___|___|	سنة
BI5	منذ متى وأنتم تسكنون هذه الشقة؟	|___|___|___|___|	
BI6	هل تم إعادة تأهيل شبكة المياه ومياه الصرف الصحي و متى؟	|___|___|___|___| 1 98 99	 لا إعادة تأهيل لا جواب لا أعلم
BI7	من المسؤول عن لجنة المبنى إذا وجدت؟	____________________ 1 98 99	 لا لجنة لا جواب لا أعلم
BI8	مساحة مسطحة________ ________ مساحة منحدرة 98 لا جواب 99 لا اعلم		مساحة سطح المبنى
BI9	نوع السطح		1 اسمنت مسطح 2 طين 3 اسفلت 4 خشب 5 الواح معدنية 6 قرميد 98 لا جواب
BI10	من لديه القدرة على الوصول إلى السطح		
BI11	متى تقوم بتنظيف السطح ؟		1 لا نقوم بتنظيف السطح 2 قبل هطول الامطار للمرة الاولى 3 كل 3 اشهر

مرة في السنة 4 لا جواب 98 لا اعلم 99	
هل يوجد خزان مشترك لسكان البناية؟ نعم 1 كلا 2 اين يوجد هذا الخزان؟ فوق (على السطح) 1 تحت 2	BI12 BI12A
اذا نعم, ما هو حجم الخزان؟ _____________ لتر ما هي استخدامات المياه في هذا الخزان؟ هل لديك موتور على سطح المبنى؟ نعم 1 كلا 2 هل تقوم بتخزين المواد الكميائية أو الفيول على السطح؟ نعم 1 كلا 2 هل لديكم خ نعم 1 كلا 2 ما هو حجم الخزان؟	B12 BI BI11C BI11D BI11E BI11F BI11G

الآن سوف أسأل عن المياه في المنزل:

مصادر المياه (Water Sources)			
WS1	ما هي مصادر المياه التي تصل الى المنزل؟		
WS1A1	شبكة المياه العامة	1	نعم
		2	كلا
		99	لا أعلم
WS1A2	مياه المشروع البلدية	1	نعم
		2	كلا
		99	لا أعلم
WS1B	بئر أرتوازي	1	نعم
		2	كلا
		99	لا أعلم
WS1C	صهريج مياه	1	نعم
		2	كلا
		99	لا أعلم
WS1D	مياه معبأة (bottled)	1	نعم
		2	كلا
		99	لا أعلم
WS1E	مياه منقولة باليد	1	نعم
		2	كلا
		99	لا أعلم
WS1F	مياه الأمطار	1	نعم
		2	كلا
		99	لا أعلم

إذا كنت تحصل على المياه من الشبكة العامّة

مياه الشبكة العامة (Network Water)			
NW1	هل تصل إليك مياه الشبكة العامة مباشرةً (من خلال حنفية خاصة للشرب في المطبخ مثلاً)؟	1 2 98 99	نعم كلا لا جواب لا أعلم
NW2	هل لديك عيار بالمتر المكعب؟	1 2 3 98 99	نعم، خاص بالشقة نعم، مشترك للبناية كلا لا جواب لا أعلم
NW3A	إذا كان لديك عيار بالمتر المكعب: ما قيمة **فاتورتك** السنويّة؟	|___|___|___|,|___|___|___|___| ليرة 97 99	 N/A لا أعلم
NW3B	ما قياس عيار الشقة؟	|___||___|.|___|___| م3 97 99	 N/A لا أعلم
NW4	ما هي استخدامات المياه التي تحصل عليها من شبكة المياه العامة	1 2 3 4 5 6 7 8	للشرب لغسل الأيدي للاستحمام لغسل الطعام للطبخ لغسل الصحون لتنظيف البيت في غرفة الغسيل

NW5A	ما وتيرة تزويد المياه عبر الشبكة العامّة في الصيف ؟	 1 2 98 99	|___| مرة في الأسبوع متقطّع لكن لا يمكن تحديد الوتيرة بشكل مستمر لا جواب لا أعلم
NW5B	كم تبقى المياه مزوّدة حين تأتي في الصيف	 1 98 99	|___|___| ساعة لا يمكن تحديد المدّة لا جواب لا أعلم
NW6A	ما وتيرة تزويد المياه عبر الشبكة العامة في الشتاء ؟	______ 1 2 98 99	مرة في الأسبوع متقطع لكن لا يمكن تحديد الوتيرة بشكل مستمر لا جواب لا أعلم
NW6B	كم تبقى المياه مزوّدة حين تأتي؟	 1 98 99	|___|___| ساعة لا يمكن تحديد المدّة لا جواب لا أعلم
NW7	هل أنت راضٍ عن نوعيّة مياه الشبكة التي تصل الى منزلك في فصل الصيف؟	1 2 97 98 99	نعم Go to NW9 لا N/A لا جواب لا أعلم

NW8	لماذا أنت غير راضٍ؟ (ممكن أكثر من جواب)	1	المياه ليست صافية
		2	هناك رائحة كلور في المياه
		3	هناك طعم للمياه
		4	المياه كلسيّة
		5	المياه تترك بقعاً على التجهيزات (المطبخ، الحمام)
		6	المياه ملوّثة
		7	المياه ذات طعمة ملوحة
		8	غير ذلك، حدد ___________________
		97	N/A
		98	لا جواب
		99	لا أعلم
NW9	هل أنت راضٍ عن نوعيّة مياه الشبكة التي تصل الى منزلك في فصل الشتاء؟	1	نعم Go To NW11
		2	لا
		97	N/A
		98	لا جواب
		99	لا أعلم
NW10	لماذا أنت غير راضٍ؟ (ممكن أكثر من جواب)	1	المياه ليست صافية
		2	هناك رائحة كلور في المياه
		3	هناك طعم للمياه
		4	المياه كلسيّة
		5	المياه تترك بقعاً على التجهيزات (المطبخ، الحمام)
		6	المياه ملوّثة
		7	المياه ذات طعمة ملوحة
		8	غير ذلك، حد ___________________
		97	N/A
		98	لا جواب
		99	لا أعلم
NW11	كيف تصنّف نوعية هذه المياه عموماً؟	1	جيدة (دون لون، طعم، رائحة، ورواسب)

		2	متوسطة (بعض اللون، طعم، رائحة، ورواسب)
		3	سيئة (ذات لون، طعم، رائحة، ورواسب)
		98	لا جواب
		99	لا أعلم

اذا كنت تحصل على المياه من الآبار

مياه الآبار (Well Water)					
WW1	عدد الآبار التي تصل منها المياه الى المنزل	|___|			
WW2 WW2A	هل كان لديك بئر قديم لم تعد تستخدمه؟ لماذا؟	1 نعم، لأنّ البئر القديم جفّ 2 نعم، لسبب آخر حدّد ________________________ 3 كلا 98 لا جواب 99 لا أعلم			
		1 **البئر 1**	2 **البئر 2**	3 **البئر 3**	4 **البئر 4**
WW3A					
WW3B	نوع البئر	1 خاص للمبنى 2 مشترك لعدة مبان 3 مشترك للحي 98 لا جواب 99 لا أعلم	1 خاص للمبنى 2 مشترك لعدة مبان 3 مشترك للحي 98 لا جواب 99 لا أعلم	1 خاص للمبنى 2 مشترك لعدة مبان 3 مشترك للحي 98 لا جواب 99 لا أعلم	1 خاص للمبنى 2 مشترك لعدة مبان 3 مشترك للحي 98 لا جواب 99 لا أعلم
WW3C	عمق البئر	|___|___|___| م |___|___|___| قسطل 98 لا جواب 99 لا أعلم	|___|___|___| م |___|___|___| قسطل 98 لا جواب 99 لا أعلم	|___|___|___| م |___|___|___| قسطل 98 لا جواب 99 لا أعلم	|___|___|___| م |___|___|___| قسطل 98 لا جواب 99 لا أعلم
WW3D	سنة الحفر	|___|___|___|___| 98 لا جواب 99 لا أعلم	|___|___|___|___| 98 لا جواب 99 لا أعلم	|___|___|___|___| 98 لا جواب 99 لا أعلم	|___|___|___|___| 98 لا جواب 99 لا أعلم

WW4A	ما هي استخدامات المياه التي تحصل عليها من البئر	1 2 3 4 5 6 7 8	للشرب لغسل الأيدي للاستحمام لغسل الطعام للطبخ لغسل الصحون لتنظيف البيت في غرفة الغسيل	
WW5	لماذا اخترت استخدام مياه الآبار؟	1 2 98 99	الحاجة إلى كمية أكبر من المياه سبب آخر، حدد ________________ لا جواب لا أعلم	
WW6	ماذا تدفع مقابل مياه الآبار او خدمة تأمين مياه البئر؟ لمن تدفع هذا المبلغ؟	1 |___|___|___|,|___|___|___| 98 99	لا شيء ألف ليرة شهرياً لا جواب لا أعلم	
WW6A	هل هناك عيار للبئر الذي تستخدمه؟	1 2 98 99	نعم كلا لا جواب لا أعلم	
WW7A	هل أنت راضٍ عن نوعيّة مياه الآبار التي تصل الى منزلك في فصل الصيف؟	1 2 97 98 99	نعم لا N/A لا جواب لا أعلم	Go to WW8A
WW7B	لماذا أنت غير راضٍ؟ (ممكن أكثر من جواب)	1 2 3 4 5 6 7 8 97 98 99	المياه مالحة المياه كلسيّة للمياه لون، حدد________________ للمياه رائحة غريبة غير رائحة الكلور، حدد____________ للمياه رائحة معدنيّة المياه تترك بقعاً \ طبقة على الأواني والتجهيزات المياه ملوّثة جرثومياً غير ذلك، حدد________________ N/A لا جواب لا أعلم	
WW8A	هل أنت راضٍ عن نوعيّة مياه الآبار التي تصل الى منزلك في فصل الشتاء؟	1 2 3	نعم لا لا أستخدم مياه البئر في الشتاء	Go To WW9

		97	N/A
		98	لا جواب
		99	لا أعلم
WW8B	لماذا أنت غير راضٍ؟ (ممكن أكثر من جواب)	1	المياه مالحة
		2	المياه كلسيّة
		3	للمياه لون، حدد______________
		4	للمياه رائحة غريبة غير رائحة الكلور حدد____________
		5	للمياه رائحة معدنيّة
		6	المياه تترك بقعاً \ طبقة على الآوني والتجهيزات
		7	المياه ملوّثة جرثومياً
		8	غير ذلك، حدد ______________
		97	N/A
		98	لا جواب
		99	لا أعلم
WW10	إذا كان الطعم مالحاً، منذ متى هذا الوضع؟		سنة |___|___|___||__|
		97	N/A
		98	لا جواب
		99	لا اعلم
WW11	هل للمبنى خزان خاص بمياه الآبار	1	نعم
		2	لا
		98	لا جواب
		99	لا أعلم
WW11A	ما هو حجم الخزان ؟	_____	لتر
WW12	هل تتم معالجة مياه البئر قبل استعمالها؟	1	نعم، يدوياً بواسطة أدوية كيمياويّة Go to WW13
		2	نعم، بواسطة فلتر Go to WW14
		3	نعم، بواسطة نظام معالجة Go to WW18
		4	كلا Go to WT1A
		98	لا جواب
		99	لا اعلم

WW13	إذا تستعمل أدوية كيمياويّة ما هي هذه المواد؟	
	إسم المادّة	ماذا يعالج؟	الكلفة السنوية بالليرة اللبنانية
WW13 A	1______	2______	3______
WW13 B	1______	2______	3______
WW13 C	1______	2______	3______

WW14	إذا كنت تستعمل فلتر، أين تضعه؟	1	على حنفيّة واحدة في المنزل، حدّد ______
		2	على عدّة حنفيّات في المنزل
		3	على خزان مياه البئر
		4	غير ذلك، حدّد ______
		98	لا جواب
		99	لا أعلم
WW15	ماذا يعالج هذا الفلتر؟	1	ملوحة
		2	لون
		3	تلوّث ميكروبي
		4	تكلّس
		5	رواسب
		6	غير ذلك، حدد ______
		98	لا جواب
		99	لا اعلم
WW16 A	ما كلفة شراء وتركيب الفلتر الواحد؟		شراء وتركيب ______ ليرة
		97	N/A
		98	لا جواب
		99	لا اعلم
WW18	ما هي وتيرة تغيير الفلتر؟	___	

	اذا كنت تستعمل نظام معالجة، ماذا يتضمن من وحدات معالجة؟			
WW19	هل يتضمن:	A محلي للمياه المالحة (Reverse Osmosis)	B تخفيف عسر المياه (الاملاح المعدنية) (Water softener)	C نظام آخر، حدد ______ أو مجموعة وحدات
		1 نعم 2 كلا 98 لا جواب 99 لا أعلم	1 نعم 2 كلا 98 لا جواب 99 لا أعلم	1 نعم 2 كلا 98 لا جواب 99 لا أعلم
WW20	سنة الشراء	|__|__|__|__| 97 N/A 98 لا جواب 99 لا أعلم	|__|__|__|__| 97 N/A 98 لا جواب 99 لا أعلم	|__|__|__|__| 97 N/A 98 لا جواب 99 لا أعلم

WW21	ماذا تعالج هذه الوحدة؟	1 ملوحة 2 لون 3 تلوّث ميكروبي 4 تكلّس 5 غير ذلك، حدد ____________ 97 N/A 98 لا جواب 99 لا اعلم	1 ملوحة 2 لون 3 تلوّث ميكروبي 4 تكلّس 5 غير ذلك، حدد ____________ 97 N/A 98 لا جواب 99 لا اعلم	1 ملوحة 2 لون 3 تلوّث ميكروبي 4 تكلّس 5 غير ذلك، حدد ____________ 97 N/A 98 لا جواب 99 لا اعلم
WW22	أين توجد هذه الوحدة؟	1 قبل الخزان الخاص بالبئر 2 بعد الخزان الخاص بالبئر 3 قبل الخزان المشترك للمبنى 4 بعد الخزان المشترك للمبنى قبل الخزانات الخاصة لكل شقّة 5 للشقّة، قبل الخزّان الخاص 6 للشقّة، بعد الخزّان الخاص 7 على حنفيّة المطبخ غير ذلك 97 N/A 98 لا جواب 99 لا اعلم	1 قبل الخزان الخاص بالبئر 2 بعد الخزان الخاص بالبئر 3 قبل الخزان المشترك للمبنى 4 بعد الخزان المشترك للمبنى قبل الخزانات الخاصة لكل شقّة 5 للشقّة، قبل الخزّان الخاص 6 للشقّة، بعد الخزّان الخاص 7 على حنفيّة المطبخ 8 غير ذلك 97 N/A 98 لا جواب 99 لا اعلم	1 قبل الخزان الخاص بالبئر 2 بعد الخزان الخاص بالبئر 3 قبل الخزان المشترك للمبنى 4 بعد الخزان المشترك للمبنى قبل الخزانات الخاصة لكل شقّة 5 للشقّة، قبل الخزّان الخاص 6 للشقّة، بعد الخزّان الخاص 7 على حنفيّة المطبخ 8 غير ذلك 97 N/A 98 لا جواب 99 لا اعلم
		B محلي للمياه المالحة (Reverse Osmosis)	C تخفيف عسر المياه (الاملاح المعدنية) (Water softener)	D نظام آخر، حدد ____________ أو مجموعة وحدات
WW23	ما كانت كلفة شراء وتركيب هذه الوحدة؟	• سعر إجمالي: ____________ ليرة • لكل شقّة: ____________ ليرة 97 N/A 98 لا جواب 99 لا اعلم	• سعر إجمالي: ____________ ليرة • لكل شقّة: ____________ ليرة 97 N/A 98 لا جواب 99 لا اعلم	• سعر إجمالي: ____________ ليرة • لكل شقّة: ____________ ليرة 97 N/A 98 لا جواب 99 لا اعلم

WW24	ما كلفة تشغيل وصيانة هذه الوحدة: أدوية، كهرباء، فلاتر.	___________ ليرة لكل شقّة في السنة 97 N/A 98 لا جواب 99 لا اعلم	___________ ليرة لكل شقّة في السنة 97 N/A 98 لا جواب 99 لا اعلم	___________ ليرة لكل شقّة في السنة 97 N/A 98 لا جواب 99 لا اعلم
WW25	هل حصل أن استبدلت هذه الوحدة؟	1 نعم 2 كلا 98 لا جواب 99 لا أعلم	1 نعم 2 كلا 98 لا جواب 99 لا اعلم	1 نعم 2 كلا 98 لا جواب 99 لا أعلم
WW26	كم كان عمر الوحدة القديمة عند الاستبدال؟	|___|___| سنة 97 N/A 98 لا جواب 99 لا أعلم	|___|___| سنة 97 N/A 98 لا جواب 99 لا أعلم	|___|___| سنة 97 N/A 98 لا جواب 99 لا أعلم
WW27	كلفة الاستبدال لكل شقة:	___________ ليرة 97 N/A 98 لا جواب 99 لا أعلم	___________ ليرة 97 N/A 98 لا جواب 99 لا أعلم	___________ ليرة 97 N/A 98 لا جواب 99 لا أعلم

اذا كنت تحصل على المياه من الصهاريج

	صهاريج المياه (Water Tankers)	
WT1	ما هي استخدامات المياه التي تحصل عليها من صهاريج المياه	1 للشرب 2 لغسل الأيدي 3 للاستحمام 4 لغسل الطعام 5 للطبخ 6 غسل الصحون 7 تنظيف البيت 8 في غرفة الغسيل

WT2	في أي شهر من السنة تبدأون عادةً بشراء المياه في الصهاريج؟	____________________ 2 على مدار السنة 3 أحياناً عند الحاجة 98 لا جواب 99 لا أعلم
WT3	عادةً، هل يطلب الصهريج للمبنى ككلّ؟	1 نعم 2 كلا ، للشقة فقط 98 لا جواب 99 لا أعلم

WT4	أين يتم تخزين مياه الصهاريج؟	1 خزان مياه الشبكة المشترك للمبنى 2 خزان مياه الشبكة الخاص بالشقة 3 الخزان الخاص بالبئر 98 لا جواب 99 لا أعلم	
	أسئلة حول استهلاك مياه الصهاريج	**A** في الصيف	**B** في الشتاء
WT5	ما هي وتيرة طلب الصهاريج؟	|___|___| مرة في الشهر 97 N/A 99 لا أعلم	|___|___| مرة في الشهر 97 N/A 99 لا أعلم
WT6	ما هو حجم الصهريج الذي تطلبه؟ **(حدّد الوحدة)**	_______________ 97 N/A 99 لا أعلم	_______________ 97 N/A 99 لا أعلم
WT7	كم تدفع مقابل مياه الصهاريج؟ **(حدد الوحدة)**	_______________ 97 N/A 99 لا أعلم	_______________ 97 N/A 99 لا أعلم
WT8	ملاحظات	_______________ _______________ _______________	_______________ _______________ _______________
WT9 WT9A	لماذا اخترت استخدام مياه الصهاريج؟	1 الحاجة الى كمية أكبر من المياه 2 مشكلة في مصادر المياه الأخرى 3 سبب آخر، ____________________________ 98 لا جواب 99 لا أعلم	

WT10A	هل أنت راضٍ عن نوعيّة مياه الصهاريج التي تصل الى منزلك في فصل الصيف؟	1 2 97 98 99	نعم لا Go to WT10B N/A لا جواب لا أعلم
WT10B	لماذا أنت غير راضٍ؟ (ممكن أكثر من جواب)	1 2 3 4 5 6 7 97 98 99	المياه مالحة المياه كلسيّة للمياه لون، حدد_______________ للمياه رائحة، حدد_______________ المياه تترك بقعاً \ طبقة على الأواني والتجهيزات المياه ملوّثة جرثوميّاً غير ذلك، حدد_______________ N/A لا جواب لا أعلم
WT11A	هل أنت راضٍ عن نوعيّة مياه الصهاريج التي تصل الى منزلك في فصل الشتاء؟	1 2 97 98 99	نعم لا Go to WT11B N/A لا جواب لا أعلم
WT11B	لماذا أنت غير راضٍ؟ (ممكن أكثر من جواب)	1 2 3 4 5 6 7 97 98 99	المياه مالحة المياه كلسيّة للمياه لون، حدد_______________ للمياه رائحة، حدد_______________ المياه تترك بقعاً \ طبقة على الأواني والتجهيزات المياه ملوّثة جرثوميّاً غير ذلك، حدد_______________ N/A لا جواب لا أعلم
WT13	هل حصل وكانت المياه مالحة؟	1 2 3 4 98 99	نعم، دائماً نعم، أحياناً نعم، في الصيف فقط كلا، أبداً لا جواب لا أعلم
WT1	ما هو مصدر مياه الصهاريج؟	1	نبع

4		2 بئر 3 شركة 98 لا جواب 99 لا أعلم
WT15	حدّد اسم المصدر ورقم التلفون إذا أمكن	____________________ /|___|___| |___|___|___||___|___|___| 98 لا جواب 99 لا أعلم
WT16	هل تعالج مياه الصهريج قبل استعمالها؟	1 نعم، دائماً 2 نعم، أحياناً 3 نعم، في الصيف فقط 4 كلا، أبداً 98 لا جواب 99 لا أعلم
WT17	ما هي طرق المعالجة المتّبعة؟	____________________ ____________________ ____________________ 97 N/A 98 لا جواب 99 لا أعلم

إذا كنت تشتري المياه المعبأة:

BW1	المياه المعبأة (Bottled Water) ما هي استخدامات المياه المعبّأة؟	1 للشرب 2 لغسل الأيدي 3 للاستحمام 4 للطبخ		
BW2	عدّد أنواع العبوات التي يستهلكها منزلك؟	A نوع 1 _______________	B نوع 2 _________________	C نوع 3 _______________
BW3	ما هي سعة العبوة؟	|___|___| ليتر 99 لا أعلم	|___|___| ليتر 99 لا أعلم	|___|___| ليتر 99 لا أعلم
BW4	كم عبوة يستهلك المنزل في الأسبوع؟	|___|___| 99 لا أعلم	|___|___| 99 لا أعلم	|___|___| 99 لا أعلم
BW5	كم تدفع عن كل عبوة؟	|___|___||___|___| ليرة 99 لا أعلم	|___|___|___|___| ليرة 99 لا أعلم	|___||___|___|___| ليرة 99 لا أعلم
BW6 BW61	لماذا اخترت استخدام المياه المعبأة؟ (ممكن اكثر من جواب)	1 طعمها أفضل 2 أسباب صحية 3 مشكلة في مصادر المياه الأخرى 4 سبب آخر ___________ 98 لا جواب	1 طعمها أفضل 2 أسباب صحية 3 مشكلة في مصادر المياه الأخرى 4 سبب آخر ___________ 98 لا جواب	1 طعمها أفضل 2 أسباب صحية 3 مشكلة في مصادر المياه الأخرى 4 سبب آخر___________ 98 لا جواب
BW7	كيف تصنّف نوعية هذه المياه؟	1 جيدة 2 متوسطة 3 سيئة 98 لا جواب	1 جيدة 2 متوسطة 3 سيئة 98 لا جواب	1 جيدة 2 متوسطة 3 سيئة 98 لا جواب

الآن سوف أسأل عن تخزين المياه في منزلك:

ST1	**عدد خزانات المياه** المستخدمة لتأمين المياه الى منزلك **(مشتركة وخاصة)**						
ST2		**1**		**2**		**3**	
		الخزان 1		**الخزان 2**		**الخزان 3**	
ST2A	لمن الخزان؟	1	خاص للمنزل	1	خاص للمنزل	1	خاص للمنزل
		2	مشترك للمبنى	2	مشترك للمبنى	2	مشترك للمبنى
		98	لا جواب	98	لا جواب	98	لا جواب
		99	لا أعلم	99	لا أعلم	99	لا أعلم
ST2B	موقع الخزان:	1	الطابق الأرضي	1	الطابق الأرضي	1	الطابق الأرضي
		2	تحت الأرض	2	تحت الأرض	2	تحت الأرض
		3	سطح المبنى	3	سطح المبنى	3	سطح المبنى
		4	تختيّة الشقة	4	تختيّة الشقة	4	تختيّة الشقة
		99	لا أعلم	99	لا أعلم	99	لا أعلم
ST2C	المادة المكوّنة للخزان:	1	معدن	1	معدن	1	معدن
		2	إسمنت	2	إسمنت	2	إسمنت
		3	بلاستيك	3	بلاستيك	3	بلاستيك
		4	إتيرنيت	4	إتيرنيت	4	إتيرنيت
ST2C1		5	غير ذلك، حدد: ___________	5	غير ذلك، حدد: ___________	5	غير ذلك، حدد: ___________
		99	لا أعلم	99	لا أعلم	99	لا أعلم
ST2D	هل الخزان:	1	مغطّى	1	مغطّى	1	مغطّى
		2	مفتوح	2	مفتوح	2	مفتوح
		3	مقفل	3	مقفل	3	مقفل
		99	لا أعلم	99	لا أعلم	99	لا أعلم
ST2E	سعة الخزان:		___ ___ . ___ ___ م^3		___ ___ . ___ ___ م^3		___ ___ . ___ ___ م^3
			___ ___ ___ ___ برميل		___ ___ ___ ___ برميل		___ ___ ___ ___ برميل
		98	لا جواب	98	لا جواب	98	لا جواب
		99	لا أعلم	99	لا أعلم	99	لا أعلم

		1		2		3	
		الخزان 1		**الخزان 2**		**الخزان 3**	
ST2F	مصادر مياه الخزان (ممكن أكثر من جواب):	1	مياه الشبكة	1	مياه الشبكة	1	مياه الشبكة
		2	مياه البئر	2	مياه البئر	2	مياه البئر
		3	مياه الصهاريج	3	مياه الصهاريج	3	مياه الصهاريج
		4	مياه الشتاء	4	مياه الشتاء	4	مياه الشتاء
		98	لا جواب	98	لا جواب	98	لا جواب
		99	لا أعلم	99	لا أعلم	99	لا أعلم
ST2G	وتيرة تنظيف الخزان:	1	ولا مرة	1	ولا مرة	1	ولا مرة
		2	عند الحاجة	2	عند الحاجة	2	عند الحاجة
		3	سنوياً	3	سنوياً	3	سنوياً
		4	كل ستة أشهر	4	كل ستة أشهر	4	كل ستة أشهر
ST2G1		5	غير ذلك، حدد ___________	5	غير ذلك، حدد ___________	5	غير ذلك، حدد ___________
		97	N/A	97	N/A	97	N/A
		98	لا جواب	98	لا جواب	98	لا جواب
		99	لا أعلم	99	لا أعلم	99	لا أعلم
ST2H	حدد الأسباب التي تدفعك إلى تنظيف الخزان	____________________ ____________________ ____________________		____________________ ____________________ ____________________		____________________ ____________________ ____________________	
		97	N/A	97	N/A	97	N/A
		98	لا جواب	98	لا جواب	98	لا جواب
		99	لا أعلم	99	لا أعلم	99	لا أعلم
ST2I	هل تتم معالجة مياه الخزان قبل استعمالها؟	1	نعم، يدويًا بواسطة أدوية كيمياويّة	1	نعم، يدويًا بواسطة أدوية كيمياويّة	1	نعم، يدويًا بواسطة أدوية كيمياويّة
		2	نعم، بواسطة فلتر	2	نعم، بواسطة فلتر	2	نعم، بواسطة فلتر
		3	نعم، بواسطة نظام معالجة	3	نعم، بواسطة نظام معالجة	3	نعم، بواسطة نظام معالجة
		4	معالج سابقا	4	معالج سابقا	4	معالج سابقا
		5	كلا	5	كلا	5	كلا
		98	لا جواب	98	لا جواب	98	لا جواب
		99	لا أعلم	99	لا أعلم	99	لا أعلم

		1 الخزان 1	2 الخزان 2	3 الخزان 3
ST2LA ST2LA1	ما هي المادة المكوّنة للخزان القديم؟	1 معدن 2 إسمنت 3 بلاستيك 4 إتيرنيت 5 غير ذلك، حدد: ________ 98 لا جواب 99 لا أعلم	1 معدن 2 إسمنت 3 بلاستيك 4 إتيرنيت 5 غير ذلك، حدد: ________ 98 لا جواب 99 لا أعلم	1 معدن 2 إسمنت 3 بلاستيك 4 إتيرنيت 5 غير ذلك، حدد: ________ 98 لا جواب 99 لا أعلم
ST3	**إذا كنت تستخدم مياه الشتاء، إشرح عن كيفية حصاد مياه الشتاء:**	________________ ________________ ________________ ________________ ________________ ________________ ________________ 97 N/A 98 لا جواب 99 لا اعلم		

الآن سوف أسألك عن تجميع مياه الأمطار

	مياه الشتاء	
RW1	إذا كنت تستخدم مياه الشتاء ، متى تم تركيب نظام تجميع مياه الأمطار	سنة______
RW2	لماذا قررت إستخدام تقنية تجميع مياه الأمطار ؟	1 لا يوجد مصدر مياه أخر 2 للتوفير من كلفة شراء مياه من مصدر أخر 3 جيد للمحافظة على البيئة 4 لتوفير مياه لري الحديقة/المزروعات 5 لتوفير مياه لتنظيف البيت 6 النظام كان مركب قبل سكننا في هذه الشقة 7 غير ذلك؛ حدد 98 لا جواب 99 لا اعلم
RW3	ما هي سعة الخزان المستخدم لتجميع مياه الأمطار ؟	1 خزان واحد أو أكثر <1000 لتر خزان واحد أو أكثر بين 1000 و–10000 لتر 2 3 خزان واحد أو أكثر> 10000 لتر 4 غير ذلك؛ حدد 98 لا جواب 99 لأعلم
RW4	ما هي نوعية الخزان المستخدم لتجميع مياه الأمطار ؟	1 حديد 2 بلاستيك 3 اسمنت 4 غير ذلك ، حدد 98 لا جواب 99 لا اعلم
RW5	إذا عندك نظام لتجميع مياه الأمطار لكنك لا تستخدمه ما هو السبب ؟	1 عملية بناء هذا النظام ليست مكتملة 2 النظام غير فعال 3 كمية الأمطار التي يمكن حصادها ليست كافية 4 لا أحب أن استخدم مياه الأمطار 5 لون مياه الأمطار التي تم حصدها ليس مقبول 6 وجود أوساخ وحشرات 7 غير ذلك؛ حدد 98 لا جواب 99 لأعلم
RW6	إذا لا يوجد عندك نظام لتجميع مياه الأمطار؛ ما هو السبب؟	1 لا يوجد مساحة خارجية للشقة لتثبيت خزانات مياه 2 هذه الشقة مستأجرة لا يوجد قساطل مياه مناسبة لنقل المياه من السطح إلى 3الخزان 4 لا أعرف/لم أسمع عن هذه التقنية كلفة تركيب

		6 لا أعتقد أن هذه التقنية ستوفر علي مادياً 7 نوعية مياه الامطار ليست جيدة 8 لا أعتقد أن هناك أي أثر ايجابي على البيئة 9 لا يوجد لدي مدخل إلى السطح 10 غير ذلك؛ حدد
RW7	هل تعتقد أن تجميع مياه الأمطار تقنية جيدة يمكن استخدامها إضافة إلى مصادر المياه الأخرى؟	1 نعم 2 كلا 98 لا جواب 99 لاأعلم
RW8	إذا لا، ما هو السبب ؟	1 كمية المياه التي يمكن الحصول عليها ليست كافية 2 أعتقد أن نوعية مياه الأمطار ليست جيدة للاستخدام لأنها ملوثة 3 كلفة الحصول على مياه الأمطار هي أكثر من كلفة أي مصادر أخرى 4 غير ذلك؛ حدد
RW9	برأيك، ما هي الوسيلة الأفضل للحصول على معلومات حول تقنية حصاد مياه الأمطار؟	1 وسائل الإعلام راديو تليفزيون جريدة 2 مراكز العمل والمدارس 3 الإجتماعات العامة والمعارض 4 رسائل نصية 5 على فاتورة المياه 6 على الإنترنت (مواقع التواصل الإجتماعي، مواقع الوزارات
RW10	هل يوجد مساحة خاصة للشقة لوضع خزان المياه؟	1 نعم 2 كلا
RW11	ما هي المساحة التي يمكن استخدامها لوضع خزان المياه؟	m^2 __________في كاراج المبنى أو تحت الأرض m^2 __________فوق الأرض
RW12	لأي اغراض برأيك يمكن أن تستخدم مياه الأمطار ؟	1 لجميع الاستخدامات المنزليه 2 لجميع الاستخدامات المنزلية ما عدا الشرب 3 للتنظيف والغسيل 4 لري المزروعات 5 لجميع الاستخدامات المنزلية والشرب في حال إستخدام نظام معالجة 6 غير ذلك حدد
RW13	في حال إقامة مشاريع حصاد مياه الأمطار عن أسطح المنازل، هل لديك رغبة للمساهمة في مثل هذه المشاريع؟	1 المساهمة بالمال 2 المساهمة بالعمل 3 لا ارغب 4 غير ذلك، حدد
RW14	ما هي الملوثات التي تتوقع وجودها في مياه الأمطار ؟	
RW15	ما هي القيمة المادية التي أنت مستعد لدفعها للحصول على نظام معالجة لهذه الملوثات	____________ليرة

الآن سوف أسألك بعض الأسئلة عن استعدادك للمساهمة في بناء شبكة لتجميع مياه الأمطار

Willingness to pay for a rainwater harvesting system		
WTPRW1	ما هو الحد المالي الأقصى الذي أنت مستعد لدفعه لبناء شبكة لتجميع مياه الأمطار ؟ في حال المصدر الحالي الذي تستخدمه لم يعد موجوداً	------------------ 98 لا جواب 99 لا أعلم
WTPRW2	هل أنت مهتم بمشاركة نظام تجميع الأمطار مع جيرانك في المبنى ؟	1 نعم 2 كلا 98 لا جواب 99 لا أعلم
WTPRW3	إذا كان هناك خطة من قبل البلدية لتجميع مياه الأمطار هل أنت مستعد لدفع أي مبلغ؟	1 نعم 2 كلا 98 لا جواب 99 لا أعلم
WTPRW4	ما هو المبلغ الشهري (الليرة اللبنانيّة) الذي تستعدّ لدفعه للمساهمة في الخطّة؟	____________________ 98 لا جواب 99 لا أعلم

سوف أطرح عليك بعض الأسئلة حول الإستعداد للدفع

Factors affecting the possibility of installing the water reuse system			
WTPWR1	ماذا يحصل لمياه الصرف الصحي في المبنى ؟	1 2 3 98 99	موصولة بشبكة التصريف العامة هناك جورة صحية جواب آخر .... لا جواب لا أعلم
WTPWR2	ما رأيك بفكرة تكرير وإعادة إستخدام مياه الصرف الصحي لأغراض منزلية كدافق المرحاض ، وتنظيف الأرضيات، وتنظيف المرآب، وغسيل السيارات وري النباتات؟	1 2 98 99	فكرة جيدة ليست فكرة جيدة. السبب: لا جواب لا أعلم
WTPWR3	ما رأيك بفكرة تكرير وإعادة إستخدام المياه الرمادية (غسيل اليدين، الإستحمام، و غسيل الثياب) لأغراض منزلية كدافق المرحاض ، وتنظيف الأرضيات، وتنظيف المرآب، وغسيل السيارات وري النباتات؟	1 2 98 99	فكرة جيدة ليست فكرة جيدة. السبب: لا جواب لا أعلم
WTPWR4	هل تمانع تعديل شبكة القساطل في منزلك لتركيب قساطل خاصة بالمياه المكررة إن كان ذلك يوفر عليك مادياً؟	1 2 98 99	نعم كلا لا جواب لا أعلم
WTPWR5	هل بنظرك أن سكان المبنى قد يدعمون مادياً مشروع كهذا إن كان يؤدي إلى خفض مصروف المياه وبالتالي يحول دون مواجهة مشكلة إنقطاع وشراء المياه في الصيف؟	1 2 98 99	نعم كلا لا جواب لا أعلم
WTPWR6	ما هو الحد المالي الأقصى الذي أنت مستعد لدفعه لتركيب نظام إعادة إستعمال للمياه	________ 98 لا 9	 لا جواب أعلم 9

WTPWR7	هل أنت مهتم بمشاركة نظام إعادة إستعمال المياه مع جيرانك في المبنى	نعم 2 98 99	 كلا لا جواب لا أعلم
WTPWR8	إذا كان هناك خطة من قبل البلدية لإعادة إستعمال المياه هل أنت مستعد للمشاركة؟	1نعم 2 98 99	 كلا لا جواب لا أعلم
WTPWR9	الذي تستعد لدفعه للمشاركة في (الليرة اللبنانية)ما هو المبلغ الشهري الخطة ؟	________ 98 99	 لا جواب لا أعلم

سوف أطرح الآن بعض الاسئلة عن العائلة والعمل:

معلومات اجتماعية وديموغرافية (Socio-Demographic and Work Information)

	SD1	ما هو عدد الأفراد الذين يسكنون في المنزل؟	|__|__|						
		SD2	SD3	SD4	SD5	SD6	SD7	WI1	WI2
	إسم الفرد الذي يسكن في المنزل:	علاقته برب المنزل:	الجنس:	سنة الولادة:	هل هذا الفرد:	أين يتعلّم حاليا؟	أعلى مستوى علمي حصّله:	هل يعمل حاليا، ما العمل الحالي:	في أيّ قطاع يعمل؟
		1 رب المنزل 2 زوجة 3 إبن \ إبنة 4 أب \ أم 5 أخ \ أخت 6 حفيد \ حفيدة 7 الصهر\ الكنة 8 غيره 97 N/A 98 لا جواب 99 لا أعلم	1 ذكر 2 أنثى	سنة |__|__|__|__|	1 لم يتعلّم **Go to SD7** 2 تعلم/ تخرج **Go to SD7** 3 يتعلم حالياً **Go to SD6** 97 N/A 98 لا جواب 99 لا أعلم	1 مدرسة خاصّة 2 مدرسة رسميّة 3 الجامعة اللبنانية 4 جامعة خاصّة 5 معهد 97 N/A 98 لا جواب 99 لا أعلم	1 لا يقرأ ويكتب 2 يقرأ ويكتب 3 إبتدائي 4 متوسّط 5 ثانوي 6 تقني 7 جامعي 8 دراسات عليا 97 N/A 98 لا جواب 99 لا أعلم	1 لا يعمل 2 صاحب مؤسسة 3 موظّف 4 ربّ عمل \ مدير 5 ربة منزل 6 متقاعد 97 N/A 98 لا جواب 99 لا أعلم	1 مؤسّسة خاصة 2 مؤسّسة عامة 3 جمعيّة 97 N/A 98 لا جواب 99 لا أعلم
A		|__|__|	|__|	|__|__|__|__|	|__|__|	|__|__| ________	|__|__|	|__|__| ________	|__|__| ________
B		|__|__|	|__|	|__|__|__|__|	|__|__|	|__|__| ________	|__|__|	|__|__| ________	|__|__| ________
C		|__|__|	|__|	|__|__|__|__|	|__|__|	|__|__| ________	|__|__|	|__|__| ________	|__|__| ________
D		|__|__|	|__|	|__|__|__|__|	|__|__|	|__|__| ________	|__|__|	|__|__| ________	|__|__| ________
E		|__|__|	|__|	|__|__|__|__|	|__|__|	|__|__| ________	|__|__|	|__|__| ________	|__|__| ________
F		|__|__|	|__|	|__|__|__|__|	|__|__|	|__|__| ________	|__|__|	|__|__| ________	|__|__| ________
G		|__|__|	|__|	|__|__|__|__|	|__|__|	|__|__| ________	|__|__|	|__|__| ________	|__|__| ________
H		|__|__|	|__|	|__|__|__|__|	|__|__|	|__|__| ________	|__|__|	|__|__| ________	|__|__| ________

سوف أطرح عليك بعض الأسئلة حول الوضع المالي العام لمنزلك:

الوضع المالي (Financial Status)				
FS1	عدد الغرف في المنزل: **فقط النوم والصالونات** (دون المطبخ، الحمام، الشرفة والمخزن/موقف السيارة)			|___|___|
FS2	هل تملك المنزل الذي تسكن فيه؟	1 2 3 98 99	نعم، ملك كلا، إيجار كلا، حدد________________ لا جواب لا أعلم	
FS3	ما هو المصروف الشهري الإجمالي للعائلة؟	 98 99	|___|___|___|,|___|___|___|,|___|___|___| ليرة لا جواب لا اعلم	
FS5	ما هو الدخل الشهري الإجمالي للمنزل؟	1 2 3 4 5 98 99	500 دولار وما دون 500-1500 دولار 1500-4000 دولار 4000 - 6000 دولار أكثر من 6000 دولار لا جواب لا أعلم	
FS6	ما عدد السيّارات التي يملكها سكّان المنزل؟	 98 99	|___|___| لا جواب لا اعلم	

ملاحظات:

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APPENDIX 2
STATISTICAL RESULTS FOR POPULATION 2

Building-level implementation

Table 14: Individually significant predictors for building-level implementation (population 2)

Factor	*Type*	*Influence*	*P value (largest)*
Existence of a shared water tank for the building	Categorical	The existence of a shared water tank decreases the willingness to implement graywater reuse at the building level	0.079
Subscription to the water authority network	Categorical	People subscribed to the network are less likely to adopt graywater reuse at their building	0.069
Annual bill to water [a] authority	Continuous	A larger yearly bill decreases the chance of adopting graywater reuse at the building level	0.065
Cost of bottled water [b]	Continuous	The increase in cost decreases the chance of adopting graywater reuse at the building level	0.089
Number of water storage tanks [c]	Continuous	The larger the number of storage tanks for a household the less likely for it to adopt the reuse of graywater	0.042
Acceptance of graywater reuse	Categorical	Graywater reuse acceptance increases the likelihood of adopting graywater reuse at their building	0.022
Perception of building residents' willingness to implement graywater reuse at their building	Categorical	Those believing that their building neighbors would support the adoption of graywater reuse are more likely to adopt it themselves	0.057

[a] Annual water bill depended on location and network(s) subscribed to. Values ranged between 100 and 400 USD, with a median of 190 USD.
[b] The survey showed diverse cost per unit of bottled water ranging from 1 to 5 USD, with a median value of 4 USD.
[c] The number of storage tanks per household ranged from 1 to 4, with a median of 2.

Table 15: Final model for building-level implementation (population 2)

Variable	*Odds ratio*	*90% conf. int. for odds ratio*	*P value*
Intercept	22.48	2.267-426.8	0.047
Non-existence of a shared water tank for the building	3.205	1.122-9.790	0.075
Disapproval of graywater reuse	0.058	0.010-0.239	0.003
Annual bill to water authority	0.982	0.967-0.992	0.016

Under a baseline condition consisting of having a shared water storage tank, accepting the idea of reusing graywater and not paying an annual water bill (hypothetically), the odds of adopting a graywater reclamation system at the building level are 22.5 to 1. Meanwhile, people who do not share a water storage tanks with their neighbors are 3.2 times more likely to implement a graywater reclamation system at their building. Furthermore, the acceptance of graywater reuse leads to an increase in the odds of adopting the technology by approximately 17 times (1/0.058), compared to not accepting the idea. Finally, an annual water bill lower by 10 USD increases the likelihood of adopting graywater reuse at the building level by approximately 20%.

Table 16: Pseudo-R^2 results of population 2 models

Model	*McFadden's method*	*Maximum likelihood method*	*Cragg and Uhler's method*
Building-level implementation	0.427	0.534	0.641
Community-level implementation	0.548	0.575	0.728

The maximum computed pseudo-R^2 for this model is 0.641 (Table 16), meaning that the model explains approximately 64% of the variability in the data, about 1.5 times better than the first model that predicts graywater acceptance. This increase is enhanced by the presence of a high leverage predictor in graywater acceptance, which is directly associated with the willingness to implement the technology at the building level.

Community-level implementation

Table 17: Individually significant predictors for community-level implementation (population 2)

Factor	***Type***	***Influence***	***P value (largest)***
Subscription to a municipal water network	Categorical	Those that have a subscription to a municipal water network are more likely to adopt graywater reuse at the community level	0.097
Acceptance of rainwater harvesting	Categorical	Disapproval of rainwater harvesting increases the willingness to implement graywater reuse at the building level	0.069
Approval to participate in a municipal rainwater harvesting plan	Categorical	The approval to participate in a municipal rainwater harvesting plan expectedly increases the likelihood of adopting a similar graywater reuse plan	0.093
Year of birth for the household head	Continuous	Younger people are more likely to adopt graywater reuse at the community level	0.048
Acceptance of graywater reuse	Categorical	Accepting graywater reuse unsurprisingly increases the likelihood of adopting it at the community level	0.041
Approval to implement graywater reuse plan at the building level	Categorical	Approval of adopting graywater at the building level also increases the odds of it being adopted at the community level	0.005

Table 18: Final model for community-level implementation (population 2)

Variable	***Odds ratio***	***90% conf. int. for odds ratio***	***P value***
Intercept	15.23	4.784-78.20	0.001
Disapproval of participating in a municipal rainwater harvesting plan	0.010	0.000-0.069	0.001
Disapproval of rainwater harvesting	417.7	8.590-3891	0.017
Disapproval of graywater reuse	0.071	0.005-0.430	0.036
Disapproval of graywater reuse at building level	0.047	0.008-0.175	0.001

Under a baseline condition consisting of accepting the idea of graywater reuse and rainwater harvesting as well as approving the implementation of building-level graywater reclamation and municipal-level rainwater harvesting, the odds of adopting a graywater reclamation system at the community level are 15.23 to 1. Moreover, the approval to participate in a municipal rainwater harvesting plan as compared to refusing it increases the likelihood of adopting municipal level graywater reuse by 100 times. Similarly, people who accept the reuse of graywater and those who approve its implementation at the building level are more likely to participate in a graywater reclamation plan at the municipal level by 14.1 and 21.3 times, respectively. However, one unexpected result was obtained as the model predicted that the disapproval of rainwater harvesting increases the odds of implementing graywater reuse at the community scale by approximately 418 times. To investigate this result, a contingency table was constructed to count the occurrences of different combinations of the two predictors (Table 19).

Table 19: Contingency for rainwater harvesting acceptance and willingness to implement graywater reuse at the community level

Willingness to implement graywater reuse at the community level	***Acceptance of rainwater harvesting***		
	Yes	***No***	***Total***
Yes	33	7	40
No	38	1	39
Total	71	8	79

The results indicate that out of the 8 responses disapproving rainwater harvesting, 7 responded positively to the implementation of graywater reuse at the community level. While the number is small compared to the total number of 79, it does explain the positive influence of rainwater harvesting disapproval on the implementation of graywater reuse at the community level. A possible explanation could be that those who disapproved rainwater harvesting are aware of its discontinued nature as it provides additional water only during the rainy season, and thus prefer a community graywater reuse plan for its potential to generate a continuous all-year-round supply of water.

This model earned a maximum pseudo-R^2 of 0.728 (Table 16) which indicates that 72.8% of the variability in the data were explained by the model. This value is the highest amongst the three population 2 models with this final model incorporating four predictors as compared to three in the first two models. The surge in the R^2 value is backed by the fact that all predictors are understandably linked to the willingness to implement graywater reuse at the community level.

APPENDIX 3
COST ESTIMATION OF BUILDING-LEVEL IMPLEMENTATION

Retrofitting costs

A typical building with 4 floors, totaling 8 apartments was adopted. The number of rooms per apartment was five. CAD drawings with the existing plumbing and desired alteration were discussed with plumbers to estimate the cost of retrofitting. The full cost of the building retrofit established after meeting the plumbers are detailed in Appendix 4 and summarized in Table 20.

Table 20: Building retrofit costs based on local plumbers' feedback

Plumber	*Location*	*Material cost (USD)*	*Labor cost (USD)*	*Total cost (USD)*
1	Batloun (rural village)	1,568	2,240	3,808
2	Beirut (urban city)	1,778	3,520	5,298

The difference in cost estimate, particularly labor cost, is due to the different locations, as Plumber 1 is based in a town in Mount Lebanon while the second is based in Beirut. Adopting the conservative costs estimated the resulting approximate retrofitting cost per apartment is around 660 USD. The value includes the cost of storage and pumping equipment, but excludes the cost of graywater treatment.

Graywater treatment system cost

The local system considered in this study consists of a single treatment tank divided internally into several smaller compartments, in which the wastewater undergoes primary sedimentation, aerated degradation (aerobic treatment), secondary clarification and disinfection. This system will serve all residents by treating a portion of the building's graywater that is required for toilet flushing. Considering a daily water consumption per capita of 180 liters (MoEW, 2012) of which 54 liters (30%) are required for toilet flushing, and a total number of building residents of 32 (8x4), then the needed volume would be 1.73 m^3/d (32x0.054). The treatment capacity of the system is 2 m^3/d, capital costs are around 5,000 USD, and yearly operating and maintenance costs are estimated at 100 USD (Ashkar, R., personal communication, 2015). These costs would be evenly shared by the 8 households of the building, resulting in a total capital cost of approximately 1,300 USD per household.

APPENDIX 4
RETROFIT COST ESTIMATES

Description	*Plumbers*			*Quantity P1*	*Quantity P2*	*Unit Price P1*	*Unit Price P2*	*Total P1*	*Total P2*
	P1	*P2*							
Ground-level graywater tank 2m³ (pre-treatment)				1	1	$ 150.00	-	$ 150.00	$ 150.00
Roof graywater tank 2m3 (post-treatment)				1	1	$ 150.00	-	$ 150.00	$ 150.00
Pump				1	1	$ 100.00	$ 100.00	$ 100.00	$ 100.00
3' drain pipes of 6m				20	3	$ 10.00	$ 12.00	$ 200.00	$ 36.00
4' drain pipes of 6m				-	16	-	$ 20.00	-	$ 320.00
3/4' PPR supply pipes (green)				26	-	$ 8.00	-	$ 208.00	
Inducer 110-75				-	16	-	$ 5.00	-	$ 80.00
T connection 110				-	16	-	$ 6.00	-	$ 96.00
PVC cement				-	4	-	$ 15.00	-	$ 60.00
1' PPR supply pipe of 4m				-	26	-	$ 10.00	-	$ 260.00
Accessories for 1' supply pipe installation				-	1	-	$ 126.00	-	$ 126.00
Accessories for pipes installation				1	-	$ 200.00	-	$ 200.00	
Labor			per bathroom	-	16	-	$ 180.00	-	$ 2,880.00
Labor for pipe installation			m	128	-	$ 5.00	-	$ 640.00	
Labor for other plumbing works			points	32	-	$ 30.00	-	$ 960.00	
Ceramic tiling			m²	16	16	$ 25.00	$ 40.00	$ 400.00	$ 640.00
Tiles			m²	16	8	$ 20.00	$ 20.00	$ 320.00	$ 160.00
painting			m²	16	-	$ 15.00	-	$ 240.00	
paint				2	-	$ 20.00	-	$ 40.00	$ 40.00
Raw materials				1	-	$ 200.00	-	$ 200.00	$ 200.00
			Total amount					$ 3,808	$ 5,298
			Cost per app.					$ 476	$ 662

APPENDIX 5
COMMERCIAL GRAYWATER TREATMENT SYSTEMS

System	***Treatment type***	***Location***	***Effluent quality***	***Flow rate m3/d***	***Capital cost ('000 USD)***	***O&M cost ('00 USD/yr)***	***Service Life (years)***
Clearwater Aquacell	MBR + UV	Australia	BOD<5mg/l TSS<1mg/l Turbidity<1NTU	0.5-100	8.8	0.10 - 0.11 cap^{-1}	>30
Nexus E-Water	Physical + UV disinfection	USA	Suitable for storage and domestic reuse	0.75	6	1	N A
Commercial Unit (Ahmed et al., 2008)	Sedimentation + Aerobic + Anaerobic+ Cl Disinfection	Oman	BOD 14.1 mg/l TSS 4.8 mg/l Turbidity 2.7 NTU	3-9	9.8-11.6	N A	10
Commercial Unit (Kuru and Luettgen, 2012)	MBR+UV	USA	BOD<4.3mg/l TSS<1mg/l Turbidity<0.2NTU	0.57	7.5	1.71	N A
Commercial Unit (Kuru and Luettgen, 2012)	Aerobic + Media filter	USA	BOD<2.4mg/l TSS<1.2mg/l Turbidity<0.5NTU	0.57	9	6.78	N A
Aquacell 800	MBR	Germany	BOD<5mg/l TSS<1mg/l Turbidity<1NTU	0.8	10	1.50	15
Greenlife GW-FB	Fixed Bed reactor	Germany	Effluent suitable for toilet flushing as well as laundry	0.25-1	Starting 2.9	N A	N A
Greenlife GWI 1.0-6.2	MBR	Germany	Effluent suitable for toilet flushing as well as laundry	0.25-6	Starting 5.2	N A	N A
Commercial system	Aeration-Sedimentation-Activated sludge	Lebanon	BOD>98% removal TSS>95% removal	2	5	1	NA