AN INVESTIGATION OF GREYWATER ONSITE REUSE POTENTIAL IN AN ARID ENVIRONMENT

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Wastewater originating from bathtubs, showers, hand basins, kitchen sinks, dishwashers and laundry machines is usually not as heavily polluted as toilet water and is thus given the name greywater. Greywater separation for onsite reuse has often been voiced as a viable option, particularly for areas suffering from water scarcity. Such areas include remote arid areas, such as desert cities and arid coastal zones. However, issues related to consistency in the quality and quantity of generated greywater were listed as challenges hindering the adoption of greywater reuse. Thus, the objective of this study was to characterize the different greywater sources for variations in the quality and quantity of greywater in households in the city of Al Ain, UAE over a period of 3 months. Samples were collected from 10 Households and tested for the typical water quality parameters (pH, turbidity, COD, and TDS). In addition, a questionnaire was designed to get an estimate of the greywater flow in the different households. Results indicate that the average daily greywater production was around 88 L per person per day. Even though the results of the water quality analysis for light greywater sources (laundry, showers, and hand basins) exhibited high variability, it was still suitable for direct irrigation. The quantification of greywater flow and potential water savings indicated that greywater could be sufficient for onsite reuse in non-crop irrigation in some of the households.

Keywords: Greywater quality, Non-crop irrigation, Water savings, Sustainability.

1 INTRODUCTION

Produced household wastewater can be classified into greywater and blackwater depending on the pollutant(s) that the water may contain. Greywater is the wastewater produced from washbasin, showers, laundry, and kitchen; whereas blackwater is the wastewater that comes from toilets. Greywater can also be divided into light and heavy greywater to indicate the concentration of pollutant(s) in the water. Water drained from washbasins, showers and laundry machines is generally classified as light greywater while wastewater from the kitchen sink is often regarded as heavy greywater, some studies have even considered it as blackwater (Noutsopoulos *et al.* 2018). Globally, many technologies are being implemented to reduce water consumption and effectively reuse wastewater. Focusing on greywater reuse has particularly gained momentum since it has low contaminant concentrations. Thus, characterizing greywater quality is an important step for evaluating the possibilities for its reuse (Eriksson *et al.* 2002). Planning greywater reuse requires a thorough evaluation of its quantity, quality, treatment options and reuse alternatives.

Greywater contribution to domestic wastewater is 60-75% of the total amount of wastewater (Kujawa-Roeleveld *et al.* 2006). Onsite greywater reuse can be for alternative activities such as garden irrigation, car washing and toilet flushing. Previous studies in the UAE focused on

measuring the daily water consumption of each household activity, the results revealed that garden irrigation and toilet flushing accounted for 673 and 195 liters per household per day, respectively (RSB 2012). Onsite greywater reuse can thus reduce the consumption of water, as well as reduce the volume of water discharged into the sewerage system and reduce water bills.

Different approaches were used to measure and calculate the quantity of the greywater produced from a household. One approach estimates the amount of greywater produced daily by recording the duration of use of the tap by each resident and for each water consuming activity. This approach typically applies to activities using water from a faucet such as showering, hand wash, or manual dish washing (Noutsopoulos *et al.* 2018). For other less frequent and constant volume activities such as the use of automatic laundry machines and dishwashers; the amount of wastewater is often calculated by recording the number of uses per day and multiplying that to the amount of water consumed per use. Previous studies have implemented this approach and successfully estimated that the average daily greywater production amounted to 98 L per person per day, and accounts for approximately 70-75% of the total household wastewater production (135 L per person per day) (Noutsopoulos *et al.* 2018). Other studies adopted a survey approach to estimate the amount of greywater produced and the public attitude towards greywater reuse. Results of a previous study applying the survey approach showed that approximately 26% of the average total household consumption was attributed to activities in the bathroom, shower, and hand basin; whereas laundry troughs and washing machines contributed 15% only (Christova-Boal *et al.* 1996). Direct quantitative approaches rely on collecting greywater over extended periods to get a more realistic quantification of daily flow. One study collected greywater over 24 hours using barrels placed underneath a building's greywater drain (Halalsheh *et al.* 2008). Dual monitoring approaches aim to increase the accuracy of greywater production. In these approached both the amount of water consumed from the tap as well as that collected from the drain are compared for verification purposes. One study implemented this approach by recording two months data of daily flow of hot and cold water in a building as well as greywater flow in drains; results show that the contribution of shower, laundry, and washbasin to greywater flow varied from 14 – 36%, 17 – 28% and 11 – 47%, respectively (Ghunmi *et al.* 2008).

In a typical UAE household, per capita water consumption ranges between 180 and 230 liters of water per day; this prompted the UAE government to explore ways to secure more resources (Qdais and Al Nassay 2001). Greywater reuse is one of the alternatives that can significantly augment water supply and help reduce pressure on freshwater resources. The Regulation and Supervision Bureau (RSB) for the water, wastewater and electricity sector in the Emirate of Abu Dhabi issued the second edition for the guide to recycled water and biosolids regulations to establish a legal framework for the safe and economic reuse of recycled water and biosolids (RSB 2018). Local planning of greywater reuse focuses on evaluating the consistency in the quality and quantity of greywater for potential onsite reuse in irrigation or toilet flushing.

The main objective of this study was to characterize the different greywater sources for variations in the quality and quantity of greywater in households in the city of Al Ain, UAE over a period of 3 months. The results are expected to inform decision makers and water planners on the best alternatives for greywater treatment and reuse. Potential water savings from greywater reuse can provide guidance for calculating the economic feasibility of greywater treatment.

2   METHODS

Field greywater sampling and quality testing as well as surveys using two questionnaires were the main investigative tools used in this study. The study was conducted in Al Ain city, which extends over an area of 15,100 km^2 and is has a population of around 760,000, living in more

than 61,000 households. The city is characterized by low rise urban development (villas and townhouses).

2.1 Greywater Sampling and Quality

Samples were collected from three different greywater sources (showers, washbasins, and laundry) from 10 households in Al Ain city. The residents were generally of high social and economic standard, which made the household consumption of water quite high. Greywater from each source was prepared by mixing the greywater samples of each activity taking place in the source (e.g. teeth brushing, hand and face washing, and shaving). Since there were no special pipes for greywater collection, the sampling protocol relied on collecting samples from drains. Accordingly, the sampling campaign resulted in a total number of 75 samples (February-June 2018 the duration of the undergraduate research project). Greywater samples were analyzed for pH, conductivity, turbidity, TSS, and COD using standard methods and calibrated instruments.

2.2 Questionnaires Development and Surveys

Two questionnaires were designed to collect information pertaining to greywater flow and potential for reuse. The first questionnaire gauged personal habits in water consumption for various greywater producing activities in each household. The survey consisted of two sections, the first section was about the participant's estimate for water consumption for each activity and the second is about the frequency at which a participant conducts each activity (Table 1). 50 residents from 10 households participated in this questionnaire, which may not be a statistically representative sample but is sufficient to give an idea of the general water consumption level. The sample was homogenous since most of the sampled households were inhabited by large families (more than 4 individuals), all inhabitants were citizens of the UAE, of similar education level (university educated), and similar lifestyle. The results were used to estimate greywater flow from each household. The second questionnaire estimates the amount of irrigation water required by each household. This questionnaire included questions pertaining to the size of the garden, type of plants, and type of irrigation used in the household. 5 households participated in answering the second questionnaire. The results were compared to the estimated greywater flow from the first questionnaire to examine the feasibility of greywater reuse in irrigation.

Table 1. Questionnaire's structure and number of participants.

	Questionnaire 1: Household water consumption	Questionnaire 2: Household landscape water use
Number of participants	50	5
Number of households	10	5
Number and type of questions	17 questions on water consuming activity 17 questions on activity frequency	2 questions on garden area 1 question type of plant 3 questions on type of irrigation 2 questions on water reuse in UAE

3 RESULTS AND DISCUSSION

3.1 Greywater Quality

Most water quality parameters exhibit a high variability within and among the different sources of greywater. Organics in the greywater of different sources varied from an average COD of 225 to 667 mg/L (Table 2). Laundry greywater had the most deteriorated water quality with

concentrations almost two times greater than the respective ones from showers and wash basins (Table 2). It is speculated that most of the detected organic carbon in laundry samples originated from the use of detergents.

Table 2. Quality characteristics of several sources of household greywater (mean ± standard deviation).

Source	pH	Conductivity (µS/cm)	TDS (mg/L)	Turbidity (NTU)	COD (mg/L)
Wash basin	7.8 ± 0.7	242.6 ± 93.7	126.0 ± 49.8	103.6 ± 130.6	224.7 ± 288.8
Shower	7.7 ± 0.9	406.3 ± 600.8	198.8 ± 301.3	77.5 ± 71.1	318.8 ± 313.1
Laundry	9.2 ± 1.0	2229.3 ± 1678.3	1023.9 ± 801.0	218.3 ± 153.8	666.6 ± 761.2
Tap water	8.3 ± 0.2	322.1 ± 89.4	161.2 ± 44.2	3.4 ± 1.5	N/A

3.2 Estimating Greywater Flow

Table 3 shows the different estimates of greywater flow for the sampled houses. It is observed that the greywater flow is affected by the size of the household (represented by the number of floors), the number of people living in the house, and the consumption habits of the residents. House number 7 has a maximum per capita greywater flow of 162 L/d which could be attributed to wasteful consumption habits. On the other hand, house number 5 had the lowest per capita greywater flow at 37 L/d.

Table 3. Estimation of greywater flow.

House #	Greywater Flow (L/d)	Number of floors	Number of residents	Average per capita flow (L/d)
1	1300	1	14	93
2	645	2	9	72
3	127	1	3	42
4	452	2	11	41
5	185	1	5	37
6	391	2	4	98
7	1459	2	9	162
8	1056	2	12	88
9	1225	2	10	123
10	607	2	8	76

3.3 Estimating Demand for Irrigation

Results from the second questionnaire were used to estimate the water consumed for irrigation and compare it with the greywater flow coming from a house. Table 4 shows that most sampled households produced greywater flow that can contribute and sometime surpass the household irrigation requirements. For example, House number 6 produces 391 L/d of greywater while it consumes 336 L/d for irrigation. On the other hand, house number 3 produces 127 L/d of greywater which is only a fraction of the irrigation water required. Household 1 produces more greywater than its irrigation needs, this excess greywater can be used for other purposes.

Table 4. Estimation of required water for landscape irrigation.

House #	Required Irrigation (L/d)	Greywater Flow (L/d)	Landscape Area (m^2)	Unit irrigation (L/d/m^2)	Type of Irrigation
6	336	391	1080	0.311	Drippers
1	759	1300	5000	0.152	Hand-held hose
3	1099	127	3000	0.366	Drippers & Hand-held hose
4	472	452	300	1.573	Drippers & Hand-held hose
8	1035	1056	2400	0.431	Drippers

3.4   Implications of Reuse

An incentive for residents to reuse greywater lies is the potential for savings on their water bills. Al Ain Distribution Company has assigned a block water tariff at different consumption rates for the residents the rate is set at 2.09 AED/cubic meter for the low consumption block and 2.60 AED/cubic meter for the high consumption block. Table 5 shows the potential savings assuming full reuse of greywater in irrigation. The calculation was made for each block tariff and the presented as monthly savings. As shown in Table 5, the maximum savings for one house reaches up to 114 AED/month while the minimum is up to 8 AED/month. Since greywater reuse could potentially have low cost, any savings can be seen as an extra incentive for the resident. The calculated savings did not consider the cost of the initial investment for greywater collection, treatment, and reuse since it would vary depending on the volume of the system and the level of subsidy that the local government is willing to provide for residents who are installing these systems.

Table 5. Potential savings from greywater reuse.

House #	Greywater Flow (L/d)	Block 1 Savings AED/month	Block 2 Savings AED/month
1	1300	81.51	101.4
2	645	40.44	50.31
3	127	7.96	9.90
4	452	28.34	35.25
5	185	11.59	14.43
6	391	24.51	30.49
7	1459	91.47	113.80
8	1056	66.21	82.36
9	1225	76.80	95.55
10	607	38.05	47.34

4   CONCLUSIONS

Greywater characteristics exhibited high variability due to its dependence on the living standard, activity, and habits of household residents. Among the analyzed sources, greywater originating from showers and wash basins showed promising water quality for direct reuse in irrigation. Since direct reuse does not entail high treatment cost, the potential savings in water bills can encourage residents to implement greywater reuse systems. Future investigations should focus on the feasibility of modular and simple treatment systems and the risks associated with the direct reuse of greywater.

Acknowledgments

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