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# Reducing water demands by adopting harvesting and recycling techniques in Pakistan

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**Key words:** Potable water, Rainwater, Greywater, Row houses and apartments, Green environment.

**Abstract**

Pakistan, being a semi-arid region of the world, is experiencing water scarcity as a major issue. There is need to find easy-to-adopt ways for mitigating freshwater needs. These include rainwater harvesting (RWH) and greywater recycling techniques. Both greywater and rainwater harvesting techniques are very important to be practiced and applied in water scarce areas of Pakistan. Two cases have been considered in a study area in Islamabad. In case-1 (row houses), 44% potable water requirements have been instantly reduced by recycling 22% less contaminated greywater and using 22% rainwater harvesting. In case-2 (apartment blocks), 25.71% potable water requirements have been instantly reduced by recycling 19.50% less contaminated greywater and by using 6.21% rainwater harvesting. The study reveals that more greywater water could be recycled in case-1 than in case-2; more rainwater could be harvested in case-1 than in case-2 as far as need for mitigation of potable water is concerned. However, more recycled greywater is available for external landscape irrigation in case-2 than in case-1. In water scarce regions, case-1 (row houses) is more preferred than case-2 (vertical apartment houses).

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## Introduction

Climate change is affecting all the countries but its effects are much pronounced for water scarce countries like Pakistan. Islamabad, the capital city of Pakistan is water-stressed due to increase in population. CDA (Capital Development Authority) fulfills the water needs of the city through number of tube wells and three major dams known as Rawal Dam, Simly Dam and Khanpur Dam. Simly and Khanpur contribute 0.382 Million cubic meter (84 Million Gallons) per day collectively. But in June 2017, these two dams experience drying rate of 50mm (2inches) per day that caused acute shortage of water supply. Losses in water distribution lines and inappropriate practices further aggravate the situation. According to United Nations Educational Scientific and Cultural Organization (2008), the groundwater level is depleting at an alarming rate of 1.70 m (67inches) per year in Islamabad. Main reason for such depletion is associated with uncontrolled pumping out of water. There is dire need to find ways to augment water scarcity and to reduce needs of fresh water usage in the city and other parts of the country.

According to United Nations Educational Scientific and Cultural Organization (2008), there were one billion people who have no availability of safe drinking water. Urban water demand is expected to become double by 2050. The climate of Pakistan is uneven and almost two third of the country demonstrate arid type climate. As per the Figs reported by WASA (Water and Sanitation Agency) Rawalpindi, during the last 30 years, ground water table in the Potohar region (Islamabad/Rawalpindi and its surroundings) has depleted by 116m (380feet). Per capita availability of water is running out on fast pace as it dropped to 850cubic meters in 2013 as compared to 5,300cubic meters in 1951. Pressure on water assets is increasing at fast pace because of increased demand and limited fresh water resources (Fletcher *et al.*, 2008; Sazakli *et al.*, 2007).

Rainwater Harvesting (RWH) is a well-known technique that has been in human practice since many hundred years. In this method accumulation and storage of rainwater is done from various elements such as rooftops, paved surfaces' runoffs and other catchments. In the rainy season of monsoon and winter, the rainfall is so concentrated that a sufficient quantity of storm water can be saved for months by applying simple harvesting techniques. This technique has great potential to make high contribution to address the risk of scarcity. It helps to stun water scarcity issues and dilapidation of land due to floods. After performing little treatment through filtration, harvested water can be applied to me*et al*most all domestic needs like bathing; washing of clothes (Laia and David, 2011), floors and face and irrigating plants and vegetation.

The rainwater has many benefits, for example, it is free; it can be collected directly and stored near the place of use which removes need of laying distribution system, it has less maintenance cost, quality of water is good for numerous uses, it lessens requirement of fresh potable water for uses other than drinking, it decreases the charges of utility bills and helps to recharge the ground water (Ishtiaq, 2016). RWH decreases the flood dangers and the load on storm drainage and sewer frameworks. As rainwater is softer, therefore it helps to reduce the usage of washing powders (Burkard *et al.*, 2000). RWH from housetop helped to meet around 16% of the residential water demand of a town in Spain that whereas this technique when applied in Jordan, saved 0.27 % to 16.6% need of fresh water (Abdulla and Al-Shareef, 2009). In case of south-eastern Brazil, RWH saved 41% average water demands (Ghisi *et al.*, 2007). Ishtiaq (2016) determined that in Rawalpindi (Pakistan), a 110 $m^2$ (25'x50') house with flat roof having sufficient size to accommodate 2 persons or 4 persons at the most may use RWH as a much beneficial technique to reduce potable water demands. Rainwater meets the WHO standards chemically and physically but when it comes to biological tests, it does not meet the WHO guidelines. The quantity of pollutants in roof rainwater depends upon surface, atmosphere and pollutants properties (Changg *et al.*, 2004; Sazakli *et al.*, 2007; Skaryska *et al.*, 2007; Villarreal and Dixon, 2005).

Quality of rainwater and its collection efficiency greatly depends upon roof area and construction material.

The most appropriate roofs for RWH are tiled and cement surfaced and a few researches state that water from housetops by and large meets the universal rules of drinking water (Dillaha and Zolan, 1984; Handia *et al.*, 2003; Sazakli *et al.*, 2007; Zhu *et al.*, 2004). The quality of rainwater in rural area is far far better than that in urban area due to their climate. It should not be expected that rainwater would achieve the drinking water standard (Jean-marc *et al.*, 2007). Good quality of RWH can be achieved by doing the primary flush from rooftops and applying chlorine dose in the storage tank. Slow sand filtration is a modest strategy to improve the bacteriological nature of water (Fewster *et al.*, 2004; Palmateer *et al.*, 1999). The Sunlight treatment technique is good for small families as it only gives 100L of water on an area of 1 square meter of sunlight (Joyce *et al.*, 1996; Sommer *et al.*, 1997; Wegelin *et al.*, 1994). Rapid Sand Filter is also used to remove suspended particles from the water (Kim *et al.*, 2005).

Water is that gift of Nature that is renewable; it can be recycled and reused. Potable water when used is discharged out in two basic forms i.e. soil (also called black) water and greywater (also called waste water). Grey water is the wastewater that comes from household sanitary system except flushes (WC) and urinals. So, recycling of Greywater is being considered as the major step towards saving needs of freshwater. In household, grey water covers about 50 to 70% of total wastewater outflow (Al-kayyousi *et al.*, 2003; Maimon *et al.*, 2010; Revitt *et al.*, 2011). The purpose of wastewater treatment is to solve technical and health problems generated by bacteria's organic and in-organic matter so that it meets the purification standards. The grey water when recycled can be used for irrigation and flushing, thus reduces freshwater availability by 50% (Maimon *et al.*, 2010). The wastewater from kitchen is not considered as part of Grey water because of the presence of bacteria and un-dissolved suspended solid particles due to food making activities (Friedler *et al.*, 2005; Hanjra *et al.*, 2012; Roesner *et al.*, 2006). Although detrimental particles are present in grey water but it is considered as an alternative water supply source and used for agriculture in many areas of world (Revitt *et al.*, 2011).

This study is aimed to find out easy to adopt ways for mitigating needs of potable (fresh) water by implement the concepts of greywater recycling and rainwater harvesting at household levels. This study will also give a comparison of two different types of community developments i.e. horizontal (row houses) and vertical (apartments). So, this study is aimed:

- To reduce pumping out of ground water which is done at large scale to meet fresh potable water demands in water scarce areas of Pakistan especially considering water shortage issues in residential areas.
- To use greywater for green developments where this greywater can be best used for irrigation in lawns and in-house plants growth.
- To promote use of rainwater and greywater recycling for residential uses at small scale level.

## Material and methods

*Study Area*

The study area is located in Zone-V of Islamabad. This site has accessibility to Islamabad Highway through Japan Road. The site is surrounded by different housing societies on all its sides. In the study area (refer Fig. 1), there are two types of construction i.e. 500 row houses (termed as case-1 in this study, each house of 25'x50' plot size) and 126 apartment blocks (termed as case-2 in this study, each block has 8 apartments) which may be labeled as horizontal and vertical density of the population, respectively. In the study area, these row houses and apartments constitute independent wings i.e. both are separated by a storm drain (called nullah in local language).


**Fig. 1.** Study Area (after google earth and SamSam model).

*Data Collection*

*Field Survey*

The field survey of the nearby population revealed that a few bores ranging up to 61 meters (200feet) exist but people suffer water shortages in the summer. Availability of underground water is an issue, that is why the owners of the society plan to carry water from tube wells proposed to be dug in a nearby (approximately 3 to 4 km away) river stream. Minimum precipitation was observed in the months of October and November whereas maximum was in the months of July and August with an average of 89mm approx. per month. Fig. 2 shows average monthly precipitation that Islamabad receives per year.

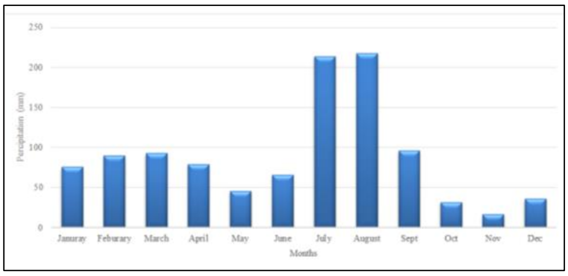


**Fig. 2.** Precipitation per month in Islamabad.

*Collection of Master plan*

Master plan of the study area was collected from the consultant firm NESPAK. The master plan shows planning and zoning of houses and construction. The master plan of the study area indicates two types of residential construction i.e. row houses and apartment blocks, as shown in Fig. 1. The said residential area is meant for the residence of labor. There exists one central road of 30meters (100feet) right of way that passes through the site and connects with the main road and with another neighboring society.

*Collection of Infrastructure standards*

The study area falls under the control of Capital Development Authority (CDA). For the calculation of water demands and sewage quantities, codes and existing practices have been followed.

*SamSam Model*

SamSam model is a universal model that has inbuilt rainfall data. It works in relation with the google earth by using which the location of the site is marked. The rainfall data which is used by the model is based on the CRU CL 2.0 dataset which is explained by New *et al.* (2002). This data was also validated by analyzing it with the 30 years' rainfall data of Islamabad.

*The Results steps followed*

*Following steps have been followed in this study*

*Step 1: Water demand.* In this step water demands for case-1 and case-2 have been worked out and this water demand has further been distributed into sub-uses which would later help to identify suitable part needed for recycling and application.

*Step 2: Quantity of sewage.* In this step quantity of sewage is calculated and bifurcated in to sub uses.

*Step 3: Identification, quantification and application of greywater for recycling.* In this step, part of sewage that could be recycled with less effort along with its preferred application has been identified and quantified.

*Step 4: Rainwater Harvesting Quantification.* SamSam model output has been obtained to determine quantity of rainwater that could be harvested and its possible application has been established. Finally, conclusions and recommendations have been made on the basis of results obtained in above step.

## Results and discussion

*Step 1: Water demand*

Water requirement per capita per day is taken as 227liters per capita per day (lpcd). Fig. 3 shows breakup of this water demand in terms of different uses. On this basis of this concept, 227lpcd water demand has been sub-divided into its component parts as given in table 1 below. Total water requirement for 500 row houses (case-1) and 1008 apartments (case-2) along with its breakup in different uses is worked out and given in table-2.

**Table 1.** Break up of per capita water demand in different uses.

| Use/Application of water | %age | Quantity |
|---|---|---|
| Drinking / cooking | 4 | 9liters/day |
| Black/flushing water | 16 | 36liters/day |
| Grey water for kitchen only | 36 | 82liters/day |
| Grey water for others[a] | 44 | 100liters/day |
| Total | 100 | 227liters/day |

[a]shower, wash basin, laundry, irrigation, floor washing

**Table 2.** Break up of water demand in different uses for case-1 and case-2.

| Description | Houses (case-1) | Apartments (case-2) | Unit of Measurement |
|---|---|---|---|
| No. of units | 500 | 1008 | |
| Residents per unit | 4 | 4 | |
| Drinking / cooking | 18,160 | 36,611 | liters/day |
| Black/flushing water | 72,640 | 146,442 | liters/day |
| Grey water for kitchen only | 163,440 | 329,495 | liters/day |
| Grey water for others[b] | 199,760 | 402,716 | liters/day |
| Total | 454,000 | 915,264 | liters/day |

[b]shower, wash basin, laundry, irrigation, floor washing

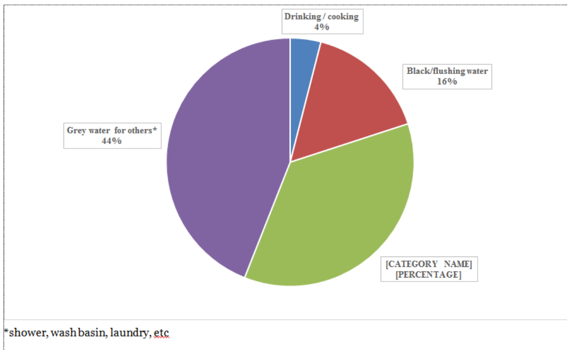


**Fig. 3.** Breakup of domestic water use distribution.

*Step 2: Quantity of sewage*

As per codes and standards, sanitary sewage is usually taken as 80 to 90% of the water requirement. The application of water into various uses suggests clearly that water required for drinking/cooking will not join the sewer. Secondly, water applied for irrigation or floor washing will also not join the sewer and these two applications are further parts of "greywater for others" in above tables. From the practices, rough estimates could be made as 45liters/day per house need for irrigating small lawn and flower pots, 22.5liters/day per apartment need for irrigating flower pots only with no lawn, and 9liters/day per house or per apartment need for floor washing. These considerations give 22700liters/day and 22880liters/day as irrigation water requirements for case-1 (500 row houses) and case-2 (1008 apartments), respectively. These considerations also give 4540liters/day and 9150liters/day as floor washing water requirements for case-1 (500 row houses) and case-2 (1008 apartments), respectively. These Fig.s when deducted from the water demand, produce a sewage generation of 172,520liters/day (out of total supplied 199760liters/day water) and 370,682liters/day (out of total supplied 402,716liters/day water). The summary of the results is shown in table 3 below.

*Step 3: Identification, quantification and application of greywater for recycling*

Greywater from kitchen contains a lot of grease and other food particles which need a sophisticated treatment to remove such objectionable contaminants before reuse. On the other hand, greywater for others* (* shower, wash basin and laundry) may require less and conventional (e.g. filtration through aggregates and sand) treatment for reuse. Hence, in these cases (refer table 3), 172,520liters/day and 370,682liters/day grey water generated from case-1 and case-2, respectively, may be recommended for re-use after filtration process only.

**Table 3.** Break up of sewage quantity in different uses for case-1 and case-2.

| Description | Houses (case-1) | Apartments (case-2) | Unit of Measurement |
|---|---|---|---|
| No. of units | 500 | 1008 | |
| Residents per unit | 4 | 4 | |
| Drinking / cooking | 0 | 0 | liters/day |
| Black/flushing water | 72,640 | 146,442 | liters/day |
| Grey water for kitchen only | 163,440 | 329,495 | liters/day |
| *Grey water for others[c]* | 172,520 | 370,682 | liters/day |
| Total | 408,600 | 846,619 | liters/day |
| %age of water demand | 90 | 92.5 | % |

*[c]shower, wash basin, laundry only.*

Keeping in view the human psyche, recycled grey water can be applied for toilet flushing, irrigation and floor washing. By applying this concept, following is inferred for case-1 and case-2:

*Case-1: Row (horizontal) houses*

Out of 172,520liters/day (38% of day demand) greywater available for re-use, only 99,880 gallons/day (22%) is comfortably utilized to meet flushing, irrigation and floor washing needs of row houses, as shown in table 4. Rest 72,640 gallons/day (difference of 172,520 and 99.880), can be directed to either a dry bore to recharge the groundwater or to improve the houses' external landscape green.

**Table 4.** Greywater application to augment potable water demand in case-1.

| Description | Potable water | Sewage | Recycled greywater | Unit of Measurement |
|---|---|---|---|---|
| Drinking / cooking | 4000 | 0 | 0 | liters/day |
| Black/flushing water | 72,640 | 72,640 | 72,640 | liters/day |
| Grey water for kitchen only | 163,440 | 163,440 | 0 | liters/day |
| *Grey water for others* | 199,760 | 172,520 | 27,240 | liters/day |
| Total | 454,000 | 408,600 | 99,880 | liters/day |
| %age of water demand saved | | | 22 | % |

*Case-2: Apartment (vertical) houses*

Out of 370,682liters/day (40.50% of day demand) greywater available for re-use, only 178,477liters/day (19.50%) is comfortably utilized to meet flushing, irrigation and floor washing needs of row houses, as shown in table 5. Rest 192,342liters/day (difference of 370,682 and 178,477), can be directed to either a dry bore to recharge the groundwater or to improve the houses' external landscape green.

**Table 5.** Greywater application to augment potable water demand in case-2.

| Description | Potable water | Sewage | Recycled greywater | Unit of Measurement |
|---|---|---|---|---|
| Drinking / cooking | 36,611 | 0 | 0 | liters/day |
| Black/flushing water | 146,442 | 146,442 | 146,442 | liters/day |
| Grey water for kitchen only | 329,495 | 329,495 | 0 | liters/day |
| *Grey water for others* | 402,716 | 370,682 | 32,034 | liters/day |
| Total | 915,264 | 846,619 | 178,476 | liters/day |
| %age of water demand saved | | | 19.5 | % |

*Step 4: Rainwater harvesting quantification*

A report of the United Nations (2009) suggests that an average yearly precipitation of 1063mm (41.85inches) is sufficient to harvest rain water and to use it in many effective ways. By applying SamSam model at the project area, it is observed that the average rainfall varies from 17.9mm (0.71 inch) in the driest month i.e. November to 289.4mm (11.40inches) in the wettest month i.e. August. The total annual rainfall in an average year is 1093mm (43inches) which is well above the above-mentioned suggested value by the United Nations (2009). So, the study site has great potential of rainwater harvesting and it would be much beneficial to augment the needs of fresh potable water by applying the concept of Rainwater harvesting as proposed by different researchers like (Ishtiaq 2016; Hamza *et al.* 2018; Osama *et al.* 2018).

SamSam model considers a runoff coefficient on the basis of type of roof and in this case for a flat roof, runoff coefficient of 0.7 has been applied by the default (but fixed) settings of the software. It means that 70% of the rain can be harvested. Following paragraphs explain the water availability and water demands for each case as worked out by applying SamSam model.

*Case 1: Row (horizontal) houses*

On the basis of above value of run off coefficient when applied to ONE house roof area of 95 square meter (1020 square foot), the SamSam model works out 1190liters (17.9mm x 95m² x 0.7) of rainwater water which can be collected in the driest month (November) and 19245liters (289.4mm x 30m² x 0.7) in the wettest month (August). The total yearly amount of water that can be collected from the roof is 72,700litres (73m³) in an average year. This total quantity (72,700liters) of rainwater collected from ONE house roof is not sufficient to fulfill the yearly house demand of 331400liters (331.42m³). SamSam model proposed a rainwater harvesting tank of 24,000liters as a sufficient volume to meet the 21.92% total water needs of one house (single unit with 4 residents) through rainwater harvesting. Table 6 shows application of rainwater harvested from the roofs of row houses.

**Table 6.** Rainwater application to augment potable water demand in case-1.

| Description | Potable water | Rainwater application | Unit of Measurement |
|---|---|---|---|
| Drinking / cooking | 18,160 | 0 | liters/day |
| Black/flushing water | 72,640 | 0 | liters/day |
| Grey water for kitchen only | 163,440 | 0 | liters/day |
| *Grey water for others* | 199,760 | 99,499 | liters/day |
| Total | 454,000 | 99,499 | liters/day |
| % age of water demand saved | | 21.92 | % |

*Case 2: Apartment (vertical) houses*

Similar to case-1, on the basis of above value of run off coefficient when applied to ONE apartment roof area of 215square meter, the SamSam model works out 2,694liters (17.9mm x 215m² x 0.7) of rainwater water which can be collected in the driest month (November) and 43,555liters (289.4mm x 30m² x 0.7) in the wettest month (August). The total yearly amount of water that can be collected from the roof is

164,500 litres (165m³) in an average year. This total quantity (164,500liters) of rainwater collected from ONE apartments' roof is not sufficient to fulfill the yearly apartment demand of 2,651,400liters (2651.36m³). SamSam model proposed a rainwater harvesting tank of 54,400liters as a sufficient volume to meet the only 6.21% total water needs of one apartment (8 units with 32 residents) through rainwater harvesting. Table 7 shows application of rainwater harvested from the roofs of row houses.

**Table 7.** Rainwater application to augment potable water demand in case-2.

| Description | Potable water | Rainwater application | Unit of Measurement |
|---|---|---|---|
| Drinking / cooking | 36,610 | 0 | liters/day |
| Black/flushing water | 146,442 | 0 | liters/day |
| Grey water for kitchen only | 329,495 | 0 | liters/day |
| *Grey water for others* | 402,716 | 56,827 | liters/day |
| Total | 915,264 | 56,827 | liters/day |
| %age of water demand saved | | 6.21 | % |

**Table 8.** Mitigating potable water demand in case-1 by applying both greywater recycling and rainwater harvesting techniques.

| Description | Potable water Demand | Mitigating potable water by applying | | Total saving | | Unit of Measurement |
|---|---|---|---|---|---|---|
| | | Greywater Recycling | Rainwater Harvesting | Quantity | %age | |
| Drinking / cooking | 18,160 | 0 | 0 | 0 | 0 | liters/day |
| Black/flushing water | 72,640 | 72,640 | 0 | 72,640 | 100 | liters/day |
| Grey water for kitchen only | 163,440 | 0 | 0 | 0 | 0 | liters/day |
| *Grey water for others* | 199,760 | 27,240 | 99,499 | 126,739 | 63.45 | liters/day |
| Total | 454,000 | 99,880 | 99,499 | 199,379 | 43.92 | liters/day |
| %age of water demand saved | | 22.00 | 21.92 | 43.92 | | % |

**Table 9.** Mitigating potable water demand in case-2 by applying both greywater recycling and rainwater harvesting techniques.

| Description | Potable water Demand | Mitigating potable water by applying | | Total saving | | Unit of Measurement |
|---|---|---|---|---|---|---|
| | | Greywater Recycling | Rainwater Harvesting | Quantity | %age | |
| Drinking / cooking | 36,611 | 0 | 0 | 0 | 0 | liters/day |
| Black/flushing water | 146,442 | 146,442 | 0 | 146,442 | 100 | liters/day |
| Grey water for kitchen only | 329,495 | 0 | 0 | 0 | 0 | liters/day |
| *Grey water for others* | 402,716 | 32,034 | 56,827 | 88,861 | 22.07 | liters/day |
| Total | 915,264 | 178,477 | 56,827 | 235,303 | 25.71 | liters/day |
| %age of water demand saved | | 19.50 | 6.21 | 25.71 | | % |

**Conclusions and recommendations**

Both greywater and rainwater harvesting techniques are very important to be practiced and applied in water scarce areas of Pakistan. In case-1 (row houses), 44% potable water requirements have been instantly reduced by recycling 22% less contaminated greywater and using 22% rainwater harvesting as shown in table 8. The leftover 16% recycled greywater could either be used to irrigate the external landscape or could be utilized to recharge the underground aquifer. Even by filtration of 36% kitchen greywater, groundwater could be recharged. All these efforts will make the area a GREEN development.

In apartment blocks (case-2), 25.71% potable water requirements have been instantly reduced by recycling 19.50% less contaminated greywater and by using 6.21% rainwater harvesting as shown in table 9. The leftover 21% recycled greywater could either be used to irrigate the external landscape or could be utilized to recharge the underground aquifer. Even by filtration of 36% kitchen greywater, groundwater could be recharged. These efforts will make the area a GREEN development.

If a comparison of case-1 (row houses) and case-2 (apartments) is drawn, it is observed that more greywater water could be recycled in case-1 than in case-2, more rainwater could be harvested in case-1 than in case-2 as far as need for mitigation of potable water is concerned. However, more recycled greywater is available for external landscape irrigation in case-2 than in case-1 and in water scarce regions, case-1 (row houses) is more preferred than case-2 (vertical apartment houses).

Restrictions on family units and sizes is also the need of the hour as identified by Ishtiaq (2016). It is also the need of the hour that the development authorities should impose need and practices of greywater recycling and rainwater harvesting techniques at household and at community levels.

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