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QUANTIFICATION AND CHARACTERIZATION OF GREY WATER GENERATED FROM MOSQUES: A CASE STUDY OF POLICE COLONY MOSQUE PESHAWAR

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I. Abstract:

Grey water generated from different sources especially from mosque is mainly focus in this research paper. Salat is one of Key pillar of Islam and Muslims are obligated to pray it five times a day. In order to pray prayer Muslims do ablution in which they washes their feet, face and hands to make them clean and prepare for offering prayer. The quantity of water used for this purpose is high as compared to be used in other hygienic activities. Therefore to make the water reusable it is necessary to investigate the water used during ablution times. For the purpose of investigation the ablution water, first we have to find its characteristics and quantity (how much water generated as grey water) and to assess its suitability for different purposes, such as for irrigation, gardening's and flushing toilets.

Filtration units is designed and constructed for collection of Grey water use during ablution. Digital flow meters along with Arduino data acquisition system is use for measurement of water usage during ablution process. Physical, chemical and biological samples were collected before and after the treatment while calculation of water consumption was done as average per capita. To assess the social attributes toward usage of grey water, questionnaire was developed. The results of tests conducted showed that the suspended solids was found 175mg/L in raw grey water while after filtration it was reduced to 79mg/L.

Key Words: *Grey water, Arduino data acquisition system, Ablution, Salat*

I. INTRODUCTION:

Allah SWT says about water in the Holy Quran that every living thing is made of water. (Surah Al-Anbiya verse# 30), and we cannot imagine life without water because it is one of the basic necessities of life besides oxygen, both for human beings and every other form of life. The countries and areas with inadequate resources of water are mainly reusing greywater for garden irrigations in the United States of America and in Japan the same greywater is reused for toilet flushing and landscaping. To conserve natural water resources, this type of recycling greywater is capable of growing the overall usage efficiency and costs reduction. An average of 18-29% as estimated that saving water could be achieved by reusing household greywater. (Lechte, 1992). While, greywater is considered as an easily available liquid fertilizer providing nutrients for plantation. (Milne 1979). Despite these potential savings and benefits greywater has been used in Australia only during severe droughts when current regulations have been temporarily relaxed to permit its reuse. Lack of regulations, guidelines and research in this specific area is Probable reasons behind the limited reuse of greywater.

Agriculture is considered to be the back bone of Pakistan economy, and is totally dependent on fresh water resources. But this scares commodity is threatened and depleting due to the rapid urbanization and increasing population. The resources of fresh water are depleting day by day due climatic changes and now the available water resources are limited. It is estimated that by 2025 the Water shortage will increase to about 31% in Pakistan, which needs some solid steps to manage the problem of water shortage. Approximately 5,600 m3 of fresh water was available per person when Pakistan came into being but now the available fresh water per person stands at 1000m3, which is alarming and putting Pakistan among the water scarce nations. (Published in the Express Tribune, March 23rd, 2013).

This research program focuses on greywater reuse as a water conservation and alternative supply option. Sinks, washing machines, bathing tubs, showers are the main sources of greywater. Greywater contains almost no pathogens and 90% less nitrogen than toilet water, so intensive treatment may not be required. The main reason for grey water reuse is the shortage and depletion of potable water resources. To meet the urban water demands, reusing greywater is the most feasible and alternative option for garden irrigation.

II. PROBLEM STATEMENT:

In Peshawar, the depth of drinking water supply tube well was from around 150 to 250 ft. in 1980s which now stands at 500 ft. In the town of Hayatabad, some ten years ago at a depth of 350ft sufficient amount of water was available, but now due to

depleting water table the depth of tube well has gone down to around eight hundred feet. In addition to this water demand is increasing day by day due to population increase together with growing migration trend to 3 Peshawar & sub-urbs, for a comparatively secure living, (due to militancy in FATA & Malakand Division), lack of basic facilities in native districts of the migrants. USAID-Pakistan has formulated a Master Plan back in May 2014 for Drinking Water, Sanitation/Storm Water and Solid Waste Services in Peshawar Khyber Pakhtunkhwa. Population projections were made for different periods over the Master Plan time domain, which were estimated as 2.58, 3.18 and 3.89 million for year 2013, 2022 and 2032 respectively. Resultantly the average day demand (ADD) for the years 2013, 2022 and 2032 are respectively, 537,300, 663,199 and 809,611 m3/day. Similarly, maximum day demand (MDD) for year 2013, 2022 and 2032 are estimated as 806,000, 995,000 and 1,214,000 m3 per day, respectively. The increasing water demand and the depleting ground water in the historical city of Peshawar is an alarming concern which need a sustainable redressal.

The burden on depleting ground water can only be minimized through optimum/efficient water use which is off course possible through water re-use. Keeping in view the above fact there is a need to quantify and characterize greywater form mosques for reuse purpose because the quality and nature of greywater in Pakistan is different from other developing countries and the greywater quality characteristics have not been investigated as yet, but the problem is to first quantify and characterize that greywater from Mosques and to find out the social acceptability of reusing greywater for irrigation of lawns and toilet flushing.

III. OBJECTIVES:

Objectives of this study are as follow,

1. Characterization of greywater from ablution area and bathrooms of mosque and reusing for irrigation of lawns and toilet flushing.
2. To determine the social acceptability of reusing Greywater.
3. To quantify the generation rates of grey water from Masjid.

For this purpose, a specially designed Arduino data acquisition system is used to quantify the greywater and to achieve the objective of reusing greywater by proposing/opting two types of filtration techniques i.e. up flow-down flow filter and slow sand filter.

IV. LITERATURE REVIEW:

Ground water reservoirs are depleting, deteriorating gradually and the quality of water is one of the grave concerns which is rising globally. The continuous consumption of fresh water is rising due to the rapid change in living standards and population growth. Earlier studies conducted shows that more than 30% of the total water consumption was used for irrigating lawns, washing cars in developed countries, of their overall water utilization regardless of their rapid urbanization and industrial growth. Hence, it is clear that in future the key concern will be the supply of enough fresh water.

Reuse of Grey Water: The household wastewater that accumulated from all other sources except that produces from the toilet is termed as greywater. The waste water which generates from kitchens, due to washing utensils in some definitions, is not included or considered as part of greywater because it contains high organic contents (Mourad et al., 2011; Aljaradin and Selim, 2011; Al Wabel, 2011; Kime et al., 2009). Thus, the greywater sources from where it generates are sinks, ablution and hand wash basin, showers, bath tub, and washing appliance. While the wastewater that is produced from toilets is termed as black water and is separate from greywater. The wastewater which are produced from the sources of household contributes about 60 to 70% to the total domestic greywater excluding the toilet and kitchen wastewater. While the other 30 to 40% wastewater is considered as black water which generates from toilet and kitchen. (Kim et al., 2009).

Reuse Grey water Advantages:

Municipal water use is one of the major uses of freshwater. Within municipal water use, drinking, cooking and personal hygiene constitute a small fraction while a significant 6 fraction is utilized for toilet flushing, laundry washing, car washing and gardening, etc. Thus, there is significant scope to divert recycled greywater towards such uses, thereby reducing the consumer's abstracted water from the municipal supplies. With the overall demand on municipal supplies thus reduced, benefits shall accrue to individuals (in terms of reduced water bills) as well as collectively in terms of lesser treatment, distribution and collection infrastructure costs (Mah et al., 2008).

Greywater Quality and Characteristics: The quality of greywater usually depends on the sources of generation i.e. bath tubs, showers, washing nature, & kitchens and the living standards and social habits of the tenants. (Khatun and Amin, 2011). The waste water produced from kitchens and toilets are normally contaminated but in contrast the greywater is less contaminated. (Aljaradin and Selim, 2011). The reason behind this is that organic matter, waste edible things and FOG's (fat, oil and grease) are not present in greywater. Previous studies show that houses having higher per capita consumptions produces greywater having different chemical and biological properties and has lower load of organic matter and concentration of total suspended solids (TSS), biochemical oxygen demand (BOD) and chemical oxygen demand (COD) as compared to the low-water consumption households. Greywater contains pathogens or Ecoli bacteria which mainly depends on the source of production. (Halalsheh et al., 2008). Previously study conducted by Chowdhury et al. (2014) in Al Ain city of UAE, he observed that coliform bacteria are present in the ablution greywater and high sodium contents have also been

reported in the previous studies conducted on greywater. If proper measures and treatments not taken for the soil having presence of high sodium ions will definitely have adverse effects on the plants and soil fertility due to accumulation of high sodium ions. (Mourad et al., 2011)

Methodology/treatment techniques:

Several treatment techniques have been introduced during the last few decades for on-site treatment of greywater. (Nitivattananon and Sa-nguanduan, 2013). The quality of greywater is dependent on the basic organic and bacteriological loads, purpose of greywater reuse, acceptance towards public, environmental and health risks, for which various countries are using various treatment techniques. Therefore, the design of treatment facility is dependent on the quality, quantity and application of greywater. (Khatun and Amin, 2011). Few of these treatment facilities/ techniques are described briefly below.

i. **Sand bed Filter Method:** The economical disinfection of greywater is possible if greywater passed through a bed of natural sand because this technique has the capability of eliminating majority of suspended and organic matters, subsequently low chlorine would be used to disinfect greywater (Mourad et al., 2011). But in most of the cases the sand filter technique is not capable of removing organic matter as shown form the practices.

ii. **Membrane Technologies:** Membrane technologies are appropriate for implementation of small and large schemes of greywater applications because they are cheap, economical, and very easy. (Nitivattananon and Sanguanduan, 2013) while Membrane technologies can significantly remove the pollutants and the removal efficiency is on higher side.

iii. **Activated Carbon Technologies** When tape water and greywater from ablution (received from mosque) were treated through activated carbon filter with ultra violet unit (for the purpose of disinfection) it was found that it removes all the contamination (impurities and pathogens) and the results were almost same for both the tape water and greywater from ablution. (Al-Wabel, 2011). Septic Tank with Sand Filter The treatment of greywater on site through septic tanks having filters with sand or wetland are the easy and effective option, and before reuse or application of greywater to lawns and home gardens, this technique of septic tanks with sand filters let the suspended matter to settle down and remove biological hazards. (Halalsheh et al., 2008).

iv. **Method of Microfiltration Membrane:** Treatment of greywater through microfiltration membrane is costly but efficient method. This technique is capable of improving the aesthetic quality of greywater and has the ability of removing suspended solids, COD, turbidity, and bacteria from the raw greywater. (Kim et al., 2009).

v. **Process of Oxidation Disinfection:** of greywater is required prior to the process of oxidation but has the capability of removing COD, suspended solids, color, turbidity and bacteria like total coliform, E-coli etc. from the household greywater. The method of oxidation is costly (Kim et al., 2009), But treatment through this method is efficient and has low costs for maintenance and operation. (Li et al., 2010).

Factors Affecting Greywater Reuse:

Primarily many countries have restricted the reuse of household greywater due to lack of awareness, costs, benefits, social, economic and technical factors, support from government, and also the main impediments are regulations. e. To spread this practice there are various challenges like lack of social acceptability, perception 13 of public toward reuse of greywater, public awareness, and lack of standards and regulations. (Khatun and Amin, 2011).

i. **Social Factors Affecting Greywater Reuse:** To reuse greywater on-site, there are various social challenges due to low quality of greywater as compared to that of municipality water. (McNeill et al., 2009). Greywater is an alternative source of water, to utilize this unconventional source, development of social perception and acceptance towards reuse is a primary factor and without this it is not possible to reuse it. (Nitivattananon and Sa-nguanduan, 2013).

ii. **Cultural Factors Affecting Greywater Reuse:** 50% and more farmers in Jordan were willing to greywater reuse for the purpose of irrigation similarly on the other side 75% inhabitants living on the west bank of Palestine, due to their local cultural values, were not willing to reuse greywater after proper treatment as shown in a previous study. (Halalsheh et al., 2008)

iii. **Economic Factors of Greywater Reuse:** The public can accept reuse of treated greywater if the cost of treatment is not high and the reuse of treated greywater is harmless as compare to raw greywater. The selection of treatment facility is dependent on the type of greywater and its usage and the cost of treatment varies accordingly. But prior to installment of greywater reuse system, to efficiently implement the reuse strategy of greywater, the economic analysis of the system to be install is necessary, because the governing factors to implement any sustainable system are the financial factors. (Mourad et al., 2011). To decrease the cost of water mains and sewer network construction, it is necessary to efficiently improve the existing sewer and water networks, because this is one of the most associated factors restricting the promotion of greywater reuse system. (Naji and Lustig, 2006).

V. Methodology:

In order to determine suitable method of reusing greywater for garden irrigation and toilet flushing, experimental greywater system was designed, installed, monitored for one month and assessed. The main objective was to assess the feasibility of reusing greywater and acceptable to the users and environment friendly.

Quality of Grey water: To determine the typical quality of greywater and any potential impact associated greywater reuse, a greywater quality sampling and testing program was developed. Following procedure were adopted to conduct the testing of Grey water

i. Three different samples were collected in three separate Bottles such as grey water (Collected from ablution area), Tap water and Filtered water for Filtration plant.
ii. Give unique identification to each sample for easiness.
iii. The sample will be delivered to laboratory within 24 Hours.

Parameter selections:

Following parameters were collected for each samples such as Physical, chemical and Biological.

i. Physical parameters: Solids, Color, taste and smell.
ii. Chemical parameters: Includes organic and inorganic parameters

a. Inorganic parameter includes Alkalinity, electrical conductivity, chlorides, sulphates and nitrogen
b. Organic Parameter includes BOD and COD were analyzed.

Color was determined by using platinum cobalt standard method and nitrate, nitrite was determined using cadmium reduction method and ferrous Sulphate method respectively. Sulphate was determined using iodometric method and indicator method was used to find alkalinity. Chloride was determined by using argentic method. Gravimetric/suction motor and probe methods were used to find suspended and dissolved solids respectively.

Data Collection:

Police Colony Masjid was selected for collection of sample and data at ablution area. Water meter was also installed to collect the greywater data. A systematic diagram of masjid was given in figure 1.

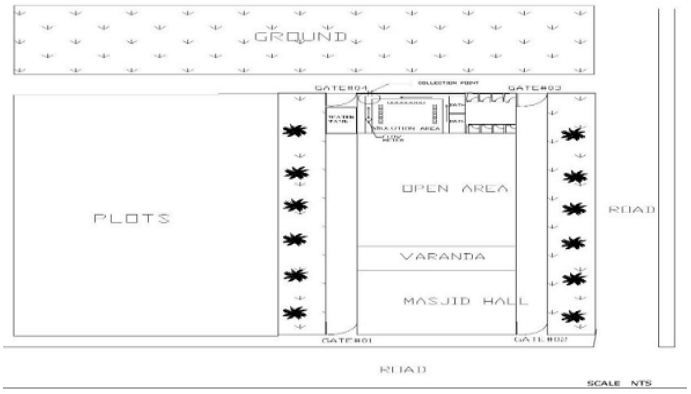

Fig: 1 systematic diagram of masjid

A simple procedure of water meter for estimating the quantity of greywater was used i.e. the amount of greywater generated from ablution (wudhu) were measured and recorded continuously for a period of one month. A digital flow meter was installed at the main water supply inlet pipe in the ablution (wudhu) area section of the Masjid. In this method, a water meter was installed at the inlet of the main pipe connecting the ablution area. It was assumed that the clean water running through the flow meter represents the amount of greywater generated. For this purpose, the digital flow meter was accompanied by Arduino data acquisition system which was programmed in such a way that it records the revolution of the flow meter after every second and stored the data in the data logger attached to the flow meter. After that the data stored in the data logger was analyzed means that the flow rate per second is multiplied by a calibrated value which was taken before the installation of flow meter to obtain the total amount water used. Some of the inflow water is used for drinking, cleaning the floor through mops or floors washing and does not return to the drain as greywater. However, such lost volumes can be safely assumed as negligible. Water meter is shown in Figure 02.

Logger Arrangement During two weeks' observation periods, the azaan and prayer iqama timings were also recorded for the five daily and

Friday prayers. This information was used in conjunction with the flow meter readings to determine the volume of water used for ablution (wudhu) for different prayers. Moreover, the number of persons doing ablution (wudhu) were regularly recorded for every prayer during the observation period.

Proposed Filtration Techniques: The most important stage in the purification of water is the process of filtration form. The following affect occurs on water during process of filtration as noticed from past experience.

i. The suspended and colloidal impurities which are present in water in a finely divided state are removed to a great extent

ii. Water chemical properties are altered
iii. Reduction of Numbers of bacteria's present in water

There are two types of filters used such as slow sand filter and up flow-down flow filter.

Slow Sand Filter: In this type of filter, inlet chamber is used through which water enters in the filter and get purified. After purification, water collected in outlet chamber and then to water storage tanks. The important parameter that was carefully managed is the height of water column over filter. Both too high and too low depths are not required. Equal depths are recommended to the height of filter media. Slow sand filters contains different layers of gravel, course and finer aggregates.

Fig: 02 Flow Meter installation and Data

The load of grey water on filter is 0.1 to 0.2 m3/m2/hr. The slow sand filter is shown in figure 3

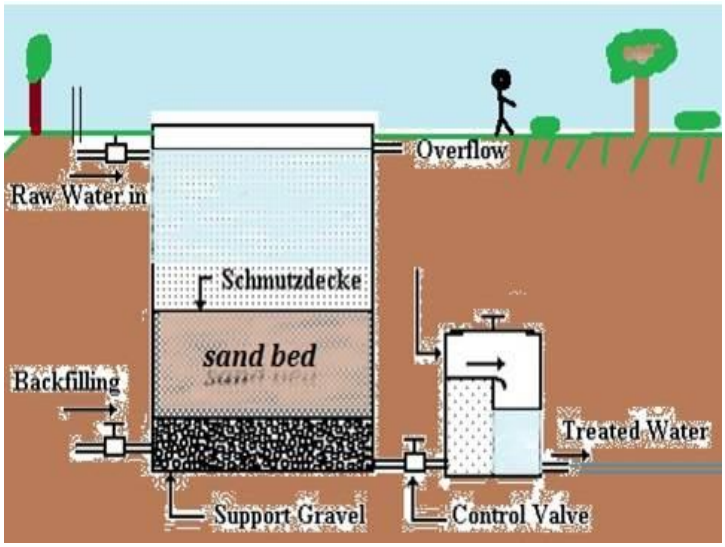

Fig: 03 Slow Sand filter Up flow-down flow filter:

It consists of four numbers of columns. Different size of gravels, finer and courser is used as filter media. The Grey water first introduced to the top of first column and flows down through the gravel media and again accumulated at the top of 2nd column of the filter unit. The grey water on the top of the 2nd column flows down to the bottom through gravel media having less size than the media of the first column. The grey water once again accumulated at the top of the 3rd column having coarser sand media through which grey water flows down to the bottom, and collected at the top of 4th column having filter media of fine sand. The up flow – down flow filter is shown in Figure 3-4 and Figure 04

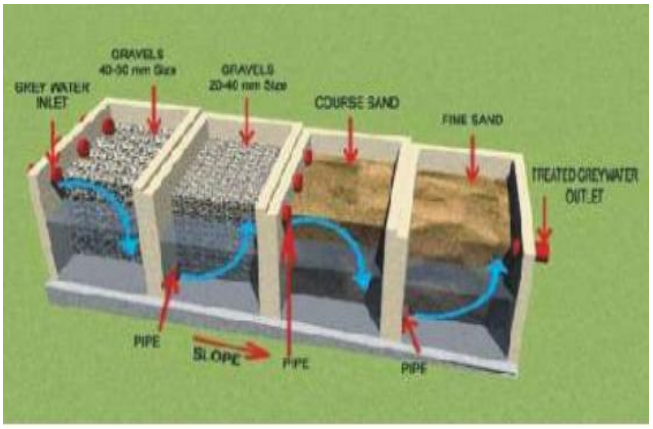

Fig: 04 Up Flow, down Flow Filter

Household Survey: Household survey is one of important part of this study to know the usage of grey water after filtration at household level. To achieve household data of grey water after filtration a questionnaire was developed with mutual understanding of supervisor and distributed randomly in 25 household to know their views. This specially design/prepared questionnaire consist of 20 questions, which was further divided into four groups. In the first six (Q 1–6) questions the respondents were asked about their social characteristics and economic characteristics i.e. adults present in the family, Number of children less than 15 years in the family, what is the level of education of respondents, what is the income of the head of the family, and how many people are living in the family, basic knowledge about greywater. In the 2nd group (Q 7-12) of questionnaire the respondents were asked about sources from where they get water, what are the different uses in houses, what is the main source of water, conservation of water, availability of storage tanks, and where the greywater discharge to. In the 3rd group (13–16) of questionnaire the respondents were asked about their interest in conservation of water. In the 4th group (Q17-20) of questionnaire the respondents were asked about reuse of grey water.

VI. Results and Discussion:

After Collection of data, results were prepared in two parts consisting experimental and social results.

Experimental results: To identify the contaminants in greywater, their concentration and the possible adverse effects associated with the greywater reuse, quality tests were conducted. During methodology three samples were collected consisting of filter water, tap water and grey water and in this phase values were determined of all parameters such as physical, chemical and biological tests. Parameters such as suspended solids, dissolved oxygen, color, Electrical conductivity, Alkalinity, chloride, nitrate, nitrite, Biological Oxygen Demand, Chemical Oxygen Demand, Dissolved solids, and sulphate were calculated for the assessment of all the three samples. World health organization was used as key standards for all three samples. The Values of all parameters of three samples were given in table 1 which clearly showed that values of grey water from designed filter was as per specified range of WHO guidelines.

Description	Tap water	Greywater	Filtered w	WHO guidelines
Suspended solids (mg/L)	2	175	79	1000
Dissolved oxygen (mg/L)	152	155	150	
Color (TCU)	4	382	197	15
Electrical conductivity (microS/cm)	304	310	300	250
Alkalinity (mg/L as $CaCO_3$)	180	160	140	250
Chloride (mg/L)	52	66	62	250
Nitrate (mg/L)	4.5	5.7	4.7	50
Nitrite (mg/L)	0.2	0.44	0.3	0.5
BOD (mg/L)	Nil	Nil	Nil	< 30
COD (mg/L)	Nil	Nil	Nil	<250
Dissolved solids (mg/L)	7.9	7.1	8	< 500
Sulphate (mg/L)	7	9	4	1

Social Survey Results:

During social survey questionnaire was developed and distributed among 25 randomly households. The results of these surveys questions are given as below

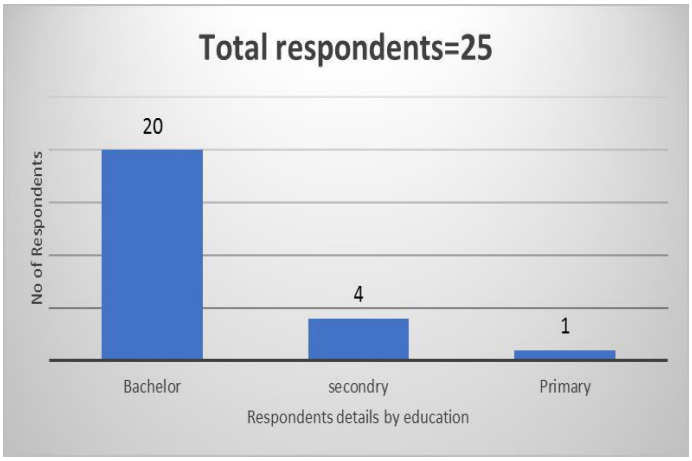

Fig: 02 Respondent by education (Comparison)

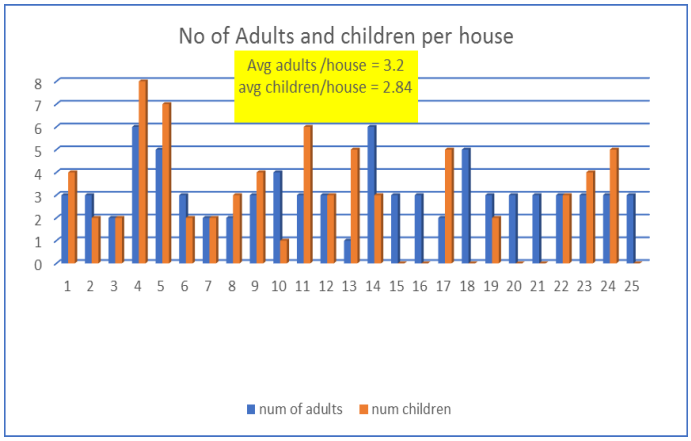

Fig: 03 Comparison of Respondents about Importance of Water Conservation

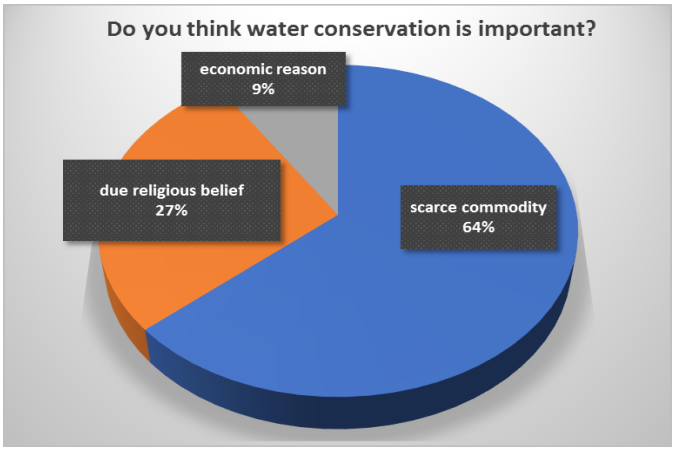

Fig: 04 Comparison of No of Adults and Children's per House

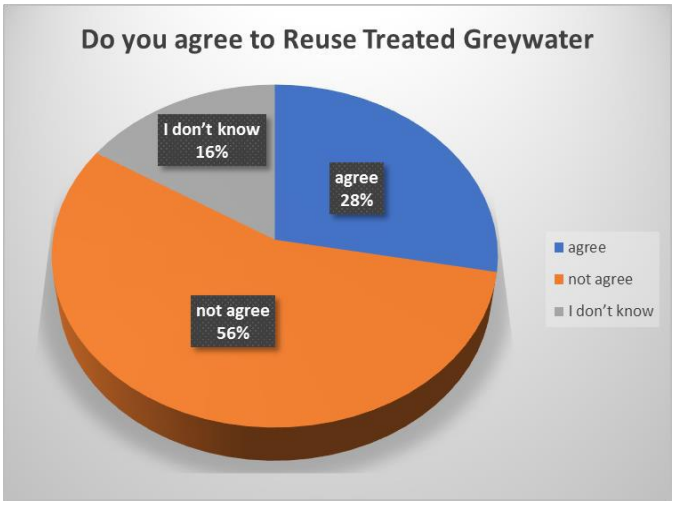

Fig: 05 Comparison of Respondents about Reuse of Treated Greywater

For rest of the questions such as given below the answers were same.

1. Residents were asked that they are Interested in water conservation. (YES).

In the questionnaire the residents were asked about their interest in conservation of water, all were interested to conserve water but there are no such facilities and guidelines available from government side.

2. Residents were asked that they are willing to adopt water conservation measures (YES).

All the residents were willing to adopt water conservation measures.

3. Residents were asked about the grey water for irrigation purpose (YES).

All the residents were agreed to use grey water for irrigation purposes.

4. Residents were asked whether separate lining for grey water and waste water systems be constructed (NO).

All the residents were not agreed to construct separate grey water and waste water systems. 36

5. Residents were asked to use grey water for toilet flushing only (YES). All the residents were agreed to use greywater for toilet flushing.

Analysis:

Experimental results clearly showed that grey water can be purified and clean by use of either filter such as slow sand or up down filter.as the water obtained from filter is colorless, odorless and tasteless.

Similarly the feedback of general public as questionnaire was distributed among the 25 households was received and given below.

i. The general public preference for greywater reuse in favor of garden irrigation and toilet flushing was 28% and 56% did not agree to use the greywater produced from kitchen, laundry. Considerable number of respondents 16% answered with "Don't Know".
ii. The public awareness of the term "Greywater" is very low, with correct understanding of greywater being 4%. It should be noted that a definition of the term "Greywater" was given in the beginning of the questionnaire.
iii. There were a number of reasons for the interest in greywater reuse. These can summarize as follow
   a. Conserving water
   b. Saving money
   c. Saving energy
   d. Saving water and money
iv. The residents were asked about the importance of water conservation, 9% stated economic reason, 27% gave the reason of religious belief, and 64% responded that water is a scarce commodity and should not waste instead should be preserved.

VII. CONCLUSIONS &RECOMMENDATIONS

1. The diversion, transfer and distribution of Masjid *(Wudhu)* greywater for garden watering is technically feasible and have no adverse effects on health but the application of greywater onto lawns and gardens should be by subsurface distribution system only to avoid uncertain hazardous health risk.
2. Although technically feasible, the reuse of greywater on typical urban allotments is not economically viable from the home owners' point of view now or in the foreseeable future, although the adoption of the practice could produce a community benefit as a result of reductions in water demand.

3. The diversion, storage and supply of greywater *(from wudhu)* for toilet flushing is technically feasible and have no potential health risk but as far as health is concerned the greywater should be properly disinfected to minimize the risk of infection through direct contact with the liquid.
4. Other parameters such as BOD Suspended Solids, Color and Turbidity have lower levels and are within the limits of standard guidelines.
5. A lot of water is wasted daily (grey water) that can be preserved by constructing filters on government level in public places, outside mosques etc.
6. Social survey was conducted to assess public opinion on greywater reuse. Results showed that a majority of the people are not even aware of the concept of greywater nor about its potential reuses. Therefore, awareness about grey water needs to be created so that people would have no objection in using recycled water.
7. It is recommended that the water authority should be motivated for educating the public about the potential value of reusing greywater and providing technical information about the typical greywater reuse system and basic design criteria.

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