Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 09, September-2016

Qualitative Characterization of Greywater from a Residential Complex in Bengaluru City, Karnataka, India

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***Abstract*- In the light of increasing water scarcity in India, the National Urban Sanitation Policy recommends a minimum of 20% reuse of wastewater in every city. This study mainly deals with the characterization of greywater generated from a residential complex in Bengaluru during various seasons. It was interpreted from the study that the influence of seasonal variations on greywater characteristics is negligible. Low organic loading in the sample indicated that it can be treated easily by simple methods and can be reused for toilet flushing and gardening thereby saving 70% of total domestic water requirement at the complex.**

Keywords - Bengaluru, Greywater, Reuse, Wastewater, Water Scarcity

I. INTRODUCTION

In 2015, NASA's satellite data revealed that 21 of the world's 37 large aquifers are severely water-stressed. With growing populations, and increased demands from agriculture and industry, researchers indicated that this crisis is only likely to worsen.

A recent European Commission report counted more than 20 million boreholes in India, up from tens of thousands in the 1960s. The water table is falling on average by 0.3 meters and by as much as 4 meters in some places. Water-starved regions often cultivate water-hungry crops like paddy, cotton and sugarcane. Punjab in the north and Tamil Nadu and Karnataka in the south continue to squabble over the ownership of rivers. The problem is not lack of adequate water, but its reckless overuse. China, with a larger population, uses 28% less fresh water than India.

This situation calls for the utilization of greywater since it is one of the main alternatives for reducing potable water consumption in households [4]. On-site greywater treatment and reuse may have a significant role in reducing overall urban water consumption, leading towards a more sustainable urban water use [3]. Greywater mainly consists of discharges from bathtubs, showers, hand washing basins and washing machines excluding wastewater from kitchen and toilet flushing system [9]. One of the biggest prospects of reusing treated Greywater is the reduction in fresh water demand and black water footprint, thereby enabling the municipal systems to lower the cost and increase treatment effectiveness [5].

The availability of harvested rain water is not regular and is influenced by climate change [6], [12], [2], [1], & [7]. Therefore greywater is one of the main alternatives for reducing potable water consumption.

The water quality requirements for each application are geo-specific but normally contain criteria based on organics, solids and microbiological content of the water. Since greywater is contributed by several activities, it is important to examine the source, quantities and characteristics of greywater in each case. As a result, this study was conducted to determine the characteristics of greywater generated from a residential complex in Bengaluru.

II. MATERIALS & METHODS

A. Study area

The study was carried out at "T-Zed Homes", a residential complex located at old Airport-Whitefield road in the city of Bengaluru (Fig. 1).

T-Zed Homes is one of the most acclaimed residential developments across the globe, sheltering high-profile families with very few such models of sustainable urban housing anywhere in the world.

The complex consists of 76 apartment houses belonging to Middle Income Group (MIG) and 15 single family houses belonging to High Income Group (HIG) in 5 acres of land and it is a "Zero Liquid Discharge" site.

The total number of inhabitants in the complex is 500. Based on the average water consumption and distribution, the average greywater production from a single house was found to be 94 Lpcd.

International Journal of Engineering Research & Technology (IJERT)
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B. Greywater Sampling

Samples from bathroom, wash basin, laundry and kitchen were collected separately at the chambers and mixed in equal proportions to obtain a homogeneous composite sample. Fig. 2 shows the layout of MIG & HIG houses at T-Zed homes along with sampling locations.

A total of 100 samples were collected (50 each from MIG & HIG houses) during October 2014-March 2015. The samples were collected in 2L plastic containers and were transferred to the laboratory in an ice-chest and cooled at 4^0C. Samples were analyzed within 24 hours after sampling.

Fig. 1. T-Zed Homes at Old Airport-Whitefield Road, Bengaluru

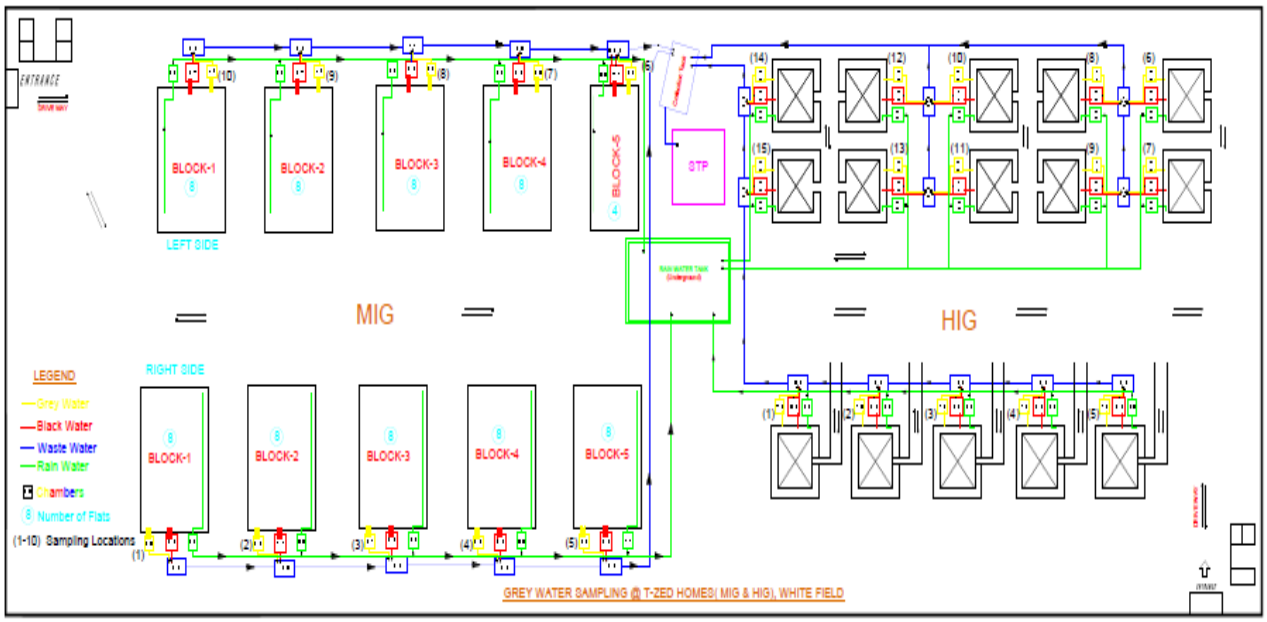

Fig. 2. Schematic representation of sampling chambers of MIG & HIG houses at the study area

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C. Analytical Methods

Standard methods [11] were followed for the analysis of water samples. For the qualitative characterization of greywater samples, several physical, chemical and biological techniques were applied. pH was analyzed using Electrometric method. TDS and TSS were measured by Gravimetric method. BOD_5 was evaluated by Winkler's method and COD was evaluated by open Reflux method. Nitrates were analyzed using PDA method and phosphates were analyzed by Stannous Chloride method.

III. RESULTS & DISCUSSIONS

A. Characteristics of Greywater

Greywater characteristics are mainly influenced by lifestyle, social, & cultural behavior of water users, availability of water, its characteristics and consumption.

Greywater generated from the study area was analyzed for physico-chemical and microbiological parameters. The physico-chemical parameters analyzed were pH, BOD_5, COD, TSS, TDS, nitrates and phosphates. Fecal Coliforms were also analyzed since bacteria can be introduced in greywater by bodily contact as well as by the use of animal meat in kitchen and through pets at home.

The primary source of water at the site is ground water which is being supplied for all purposes

Table 1 shows the characteristics of physico-chemical and microbiological parameters analyzed during various seasons at the site. including flushing of toilets after subjecting to Reverse Osmosis treatment. Hence RO treated water is the secondary source of water which is actually supplied for end uses.

pH of the samples varied between 5 to 6.5 (Graph 1 of Fig. 3) for greywater generated from MIG houses and 7.4 to 9.1 for greywater generated from HIG houses. The main reason for acidic range of pH of greywater from MIG houses is the source water. As mentioned earlier, the source of supplied water for all end-uses is RO treated water with pH in the range of 5 to 6. High organic content in the greywater made the pH persist in the acidic range. Whereas, pH of greywater from HIG houses is marginally neutral except in the month of March since the organic content was quite low during this month and low organic content does not increase the pH.

As seen in Graph 1, there are no prominent seasonal variations with respect to pH.

Table 1. Characteristics of physico-chemical and Microbiological parameters

Month	pH		BOD (mg/L)		COD (mg/L)		TSS (mg/L)		TDS (mg/L)		Nitrate (mg/L)		Phosphate (mg/L)		FC (MPN/100ml)	
	MIG	HIG	MIG	HIG	MIG	HIG	MIG	HIG	MIG	HIG	MIG	HIG	MIG	HIG	MIG	HIG
Oct	6	7.4	41	36	144	135	300	50	144	170	1.58	0.67	6.2	6	521	625
Nov	5.7	7.4	35	36	180	148	86	50	183	158	2	1.02	7.05	8.5	600	710
Dec	5	7.6	102	44	123	250	188	56	212	180	2.5	2	11.5	12.8	875	980
Jan	6	7.6	138	46	540	300	310	62	209	296	3.5	2.3	12	11.7	1118	1021
Feb	5.7	7.7	62	31	168	215	86	50	166	230	1.8	1.5	8.8	7.1	1023	1110
Mar	6.5	9.1	52	43	135	254	150	62	190	280	1.65	1.35	9	9.2	1157	1200

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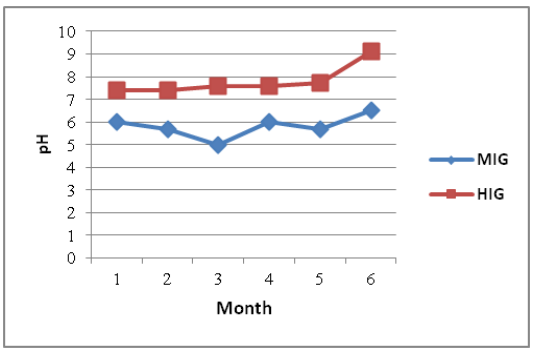
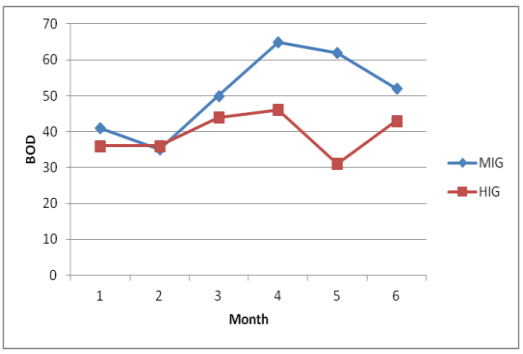
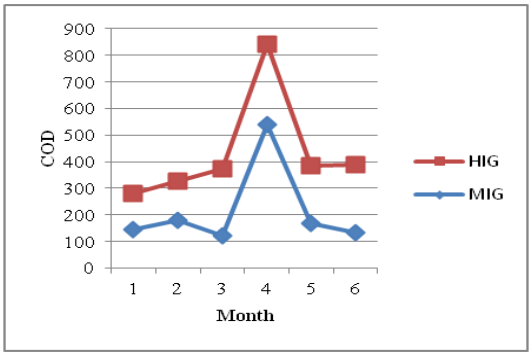


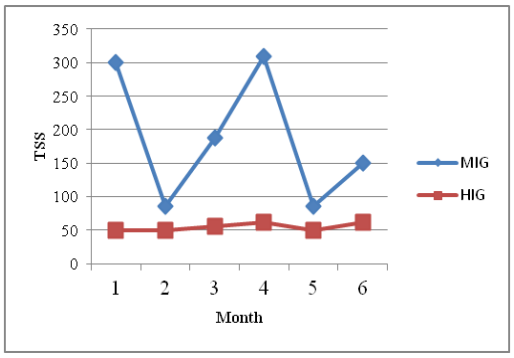
Graph 1



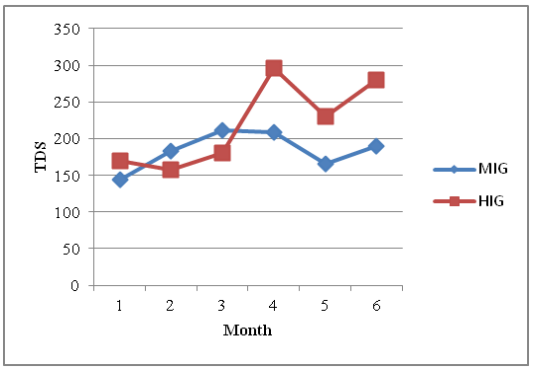
Graph 2



Graph 3



Graph 4



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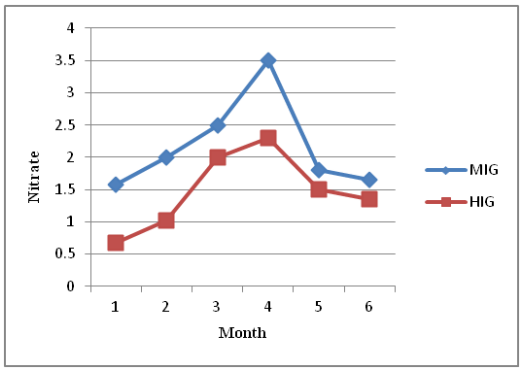
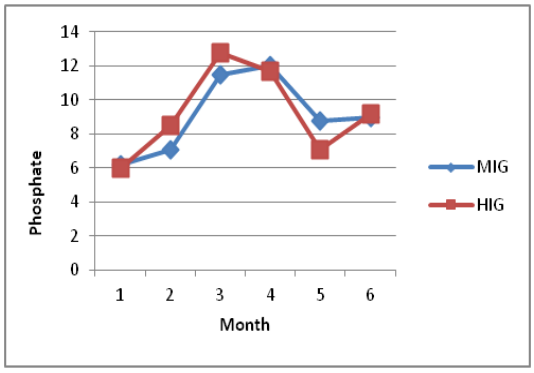
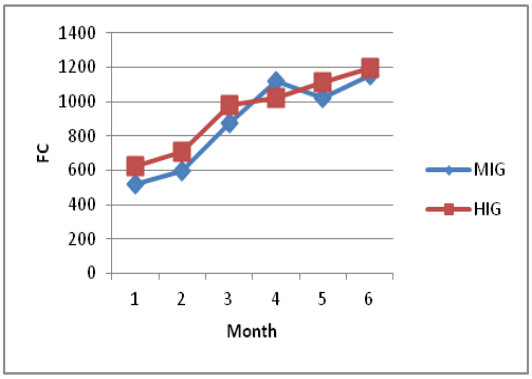


Graph 6



Graph 7



Graph 8

Fig. 3. Seasonal variations of physic-chemical and microbiological parameters

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BOD of MIG samples varied between 35 mg/L to 138 mg/L and that of HIG samples varied between 31 to 46 mg/L (Graph 2). On the other hand, COD values varied between 123 mg/L to 540 mg/L for MIG and 135 mg/L to 300 mg/L for HIG (Graph 3). The reason for high BOD & COD values of greywater from MIG houses when compared to HIG houses is the difference in lifestyle of the people living in these sectors. The high usage of instant food rather than home-made food and the health conscious attitude of the people living in HIG houses may be the reason for low organic content in turn influencing the TSS concentration. The same reason holds good for TSS concentration which lies in the range of 86 mg/L to 310 mg/L for greywater from MIG houses and 50 mg/L to 62 mg/L for greywater from HIG houses (Graph 4) since the main source of TSS in greywater is high amounts of food particulates, fibers, oil, fat and foam from kitchen greywater.

There was no much difference in the COD values of greywater generated from both the groups. The reason behind this is the common anthropogenic activities in both the groups such as use of detergents, body care products, tooth paste, shaving waste etc. which adds up to COD. However, the value of BOD, COD and TSS is quite high in the month of February when compared to other months due to high temperature which enhances the rate of degradation of organic matter and one more reason being the anthropogenic disturbance during that time due to a social gathering at one of the houses as observed during the survey.

The TDS values varied between 144 mg/L to 212 mg/L for greywater from MIG houses and 158 mg/L to 296 mg/L for greywater from HIG houses (Graph 5). The TDS values in this study got elevated mainly due to use of detergents, body care products and dissolved elements from plumbing and piping elements.

Apart from organic content, nutrients will also be present in greywater. The major nutrients which were present in the collected samples were nitrates and phosphates. Nitrates get added up in greywater mainly through kitchen wastewater. It gets added in kitchen wastewater through food sources such as beans, cooked rice, milk (full cream), beef and lamb (lean meat, cooked), cheese, cornflakes, eggs, greens, cooked potatoes and peas. The nitrate value in greywater from MIG houses ranged from 1.58 mg/L to 3.5 mg/L whereas it ranged from 0.67 mg/L to 2.3 mg/L for greywater from HIG houses (Graph 6). Except in the month of January, the value of nitrates has remained quite low in other months. One more important nutrient that was present in the samples was phosphate. Phosphates were present in greater amounts when compared to nitrates since detergents, soaps, and other cleaning agents will be widely used in every household. The value of phosphates ranged from 6.2 mg/L to 12 mg/L in greywater generated from MIG houses and 6 mg/L to 12.8 mg/L in greywater generated from HIG houses (Graph 7). The values have reached 11.5 mg/L and 12.8 mg/L due to the life style of people in the complex which includes usage of high amounts of soaps, detergents and cleaning agents when compared to other households. The concentration of fecal coliforms increased exponentially in both MIG as well as HIG houses. The concentration was high in the months of January, February and March (Graph 8) due to high temperature which is favors the growth and multiplication of the organisms.

According to the results, greywater generated from this complex presents low concentration of TSS, TDS and more importantly low organic loadings when compared to the concentrations and loadings mentioned in previous studies conducted in India. For instance, in the study conducted by [8], on characterization of greywater only from bathrooms and washbasins of a hostel, the values of BOD_5 and COD are as high as 188.3 mg/L and 374.8 mg/L and in another study conducted on recycling of greywater (including kitchen wastewater) generated from a single family in Bhopal, India [10], the values of BOD_5 and COD are as high as 108 mg/L and 586 mg/L respectively. This indicates that the influence of seasonal variations is very less or negligible and the most important factor influencing the variation in greywater characteristics are the socio-economic and cultural factors. In view of the fact that the lifestyle of the people residing in the study complex is quite lavish, the quality of greywater generated is better in terms of organic loading than that generated from other complexes/buildings irrespective of the economic sector to which they belong (MIG/HIG).

B. Recycling of Greywater

Greywater collected from the study area provides a good opportunity for recycling and reusing knowing that it can be easily collected for treatment since a separate pipeline already exists for collecting greywater.

By reusing the generated greywater for flushing and gardening, 70% of the total domestic water demand in the complex can be reduced which saves approximately Rs. 10.30 lakhs/annum and indirectly helps to reduce the ground water exploitation at the site.

IV. CONCLUSIONS

In the present study, the overall qualitative characteristics of greywater from a residential complex were analyzed. It was found from the study that the influence of seasonal variations on greywater characteristics is negligible since it mainly depends on the lifestyle, social and cultural behavior of the people and characteristics of source water and consumption. Hence the quality of greywater generated in the complex is good in terms of organic loading because of the sumptuous lifestyle of the people residing in the complex irrespective of the economic sector (MIG/HIG) to which the houses belong. Due to low organic and nutrient content, the greywater can be easily treated by simple treatment methods such as Electrochemical Advanced Oxidation Process (EAOP).

By recycling the generated greywater for toilet flushing and gardening, 70% of the total domestic water requirement can be reduced at the complex in turn saving Rs. 10.3 lakhs/annum, thereby helping to reduce the groundwater exploitation at the site.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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