A Low-Cost Decentralized Grey Water Recycling System for Toilet Flushing

N. Bhanu Sree

Abstract Water is the gifted resource which is needed by each and every living kind on this Earth. It is the part and parcel of all functions we do. The first most used resource is finding its shortage since the Industrial Revolution has been started. Water is used for many purposes where it is not required to maintain its drinking water standards for all activities. For example, toilet flushing, car washing, gardening and irrigation do not require exactly the potable standards. Relaxation on water demand and wastage can be given going for recycling. Grey water is used, and water collected from washbasin, kitchen sink and laundry activities constitutes about 33.33%. Thus, grey water collected from a residential area has given a simple treatment to make it fit to use for toilet flushing. Due to European toilet system, users even started wasting the potable water. Decentralized system confined to specific colony, i.e. individual colony is responsible for the treatment. It helps in reducing load on STP. This study concentrated on enhancing grey water aesthetic appearance by providing treatment units like aeration, two-stage filtration and disinfection.

Keywords Grey water · DO · COD · Detention timem ROF

1 Introduction

Increase in population has put great stress on energy and water resources. India is the second most populous with more than 1.35 billion. It has estimated the water demand increase from 710 BCM (Billion Cubic Metres) in 2010 to almost 1180 BCM by the year 2050 [1]. With domestic and industrial water, consumption is expected to increase almost 2.5 times. Increase in demand and wastage is making really to fight for water in between nations and states. Water after usage turns into sewage which can be classified and can be segregated into black water and grey water. Black water emerges from the toilets (urine, faeces), whereas grey water emerges from sinks, shower bath, kitchen and laundry activities [2]. A little relaxation on water demand

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and wastage can be given going for recycling. Recycling is the one of the Rs. 4 concept and adopts management of wastewater by passing over some process.

The first case of grey water treatment was mentioned in 1975 by the NASA [3]. In Sweida city of Syria, 83% people were willing to use treated grey water understood by conducting house interviews [4]. As grey water measures for up to 75% of the wastewater produced in households [2], the average generation of grey water changes from country to country varying from 90 to 120 LPCD [5], Morel and Diener [2] which varies depending on the age, living standards, gender and amount of water available. A simple treatment of grey water cannot be used for drinking purpose but can be used for secondary purposes like gardening, flushing of toilets, car–bike washing and firefighting. For example, reusing grey water for irrigation in the city Los Angeles reduced 12–65% of freshwater usage annually [6]. Grey water used for toilet flushing saves 29–35% of common per capita demand. The degree of treatment depends on the quality of grey water which again depends on the source from which it is drawn as well as for the purpose it is used, but there are general characteristics that can be applicable [7]. Grey water can be classified into two categories based on pollutant loads, i.e. high and low load pollutants [8]. According to [5], grey water collected from the kitchen basin and washing machine is higher in organic and physical pollutants compared to bathroom and mixed. Grey water consists of discharges from kitchen and washing machine mostly consists of inorganic particles with very less biodegradability or not even [8]. The BOD: COD ratio of grey water is reported as 0.25–0.64 [8, 9] thus giving an idea of biodegradability. The first priority is given to improve physical parameters as the aestheticism is considered as basic for the end–user, and a considerable improvement was also made in the chemical and biological parameters. Khaldoon et al. (2011) study was conducted in the city of Sweida of Syria. The main objective of the study is to decrease the usage of potable water by constructing artificial wetland (AW), a commercial bio filter (CBF) would save 35% of drinking water for flushing of toilets, and this is also a good practice but requires large area which is not possible in urban areas. Abdel-Kader [10] constructed the mathematical model used to investigate the performance and treatment capability of rotating biological contactors (RBC) to treat the grey water. The GPS-X (version 5.0) simulation program was used in this study to simulate the proposed RBC plant.

Sand filters arranged in series 1 and 2 can reduce COD up to 90% and 84% [11] studied the long-term performance of using natural fibre-based biofilms at moderate and low organic loading rates (OLR) have been examined. Biofilms made of natural fibres (coir, ridge gourd) were similar to that of synthetic media (PVC, polyethylene) at lower OLR when operated in pulse fed mode without effluent recirculation and achieved 80–90% COD removal at HRT of 2 d. But it is not reliable in our laboratory. So, the specific objective of the study is to study of characteristics of grey water like pH, temperature, conductivity, turbidity, TDS, DO and COD studying the amount of reduction in characteristics with aeration and slow sand filtration.

2 Materials and Methods

2.1 Study Area

Gujarat is a state located at the western part of India. The major rivers are Sabarmati, Tapi, Narmada and Mahi making Gujarat yielding great amount of water. Though water scarcity is not a problem but could happen due its sharp growth in industrialization. The present study area Palanpur located in Banas kantha district with coordinates 24.17 °N 72.43 °E consists of 1.41,592 populations according to Census 2011. There is rapid increase in population since 1981 (61,300), 1991 (90,300), 2001(122,300) due to the increase in all facilities including a domestic airport at Deesa just 26 km from Palanpur town. Veer city residency is situated near Ahmadabad highway. The building consists of flushing system which utilizes large quantity of water.

2.2 Quantification and Collection of Grey Water

Before starting the experimental work, it is essential to know the amount of grey water coming out from different sources so that one will get an idea of how much to be treated and for how much system can be designed. The following two methods direct method and bucket method were easy to apply in the field for collection and also measuring the quantity.

2.2.1 Direct Method

In this method, water metre is fixed at the outlet of the drain in kitchen, washbasin, washing machine and RO filter. This not possible metre can be adjusted in between the storage tank and kitchen, washbasin, washing machine, RO filter inlets. By using this method, we can easily determine the quantity of grey water.

2.2.2 Bucket Method

In this system, quantity of grey water is collected by placing the bucket at the drain from kitchen, washbasin, washing machine and RO filter. This method is cheap, and it is applicable where the grey water is kept constant.

2.2.3 Method Followed

Bucket method is used in the study to determine the quantity. First, the outlet was determined and then a 20 L bucket is placed at all drains. The time required to fill

Table 1 Quantity of grey water from different sources

Source of grey water	Quantity (lit/day)
Washing machines	85
Kitchen sink	80
R.O. system	45
Total (from a house)	**210**

is noted down, measured the rate of flow of grey water at all peak times and also recorded 24 h discharge. This process was continued for one week. All the values were averaged, and finally determined the grey water can be obtained for a day. Table 1 shows house survey is conducted in each 12 houses of Veer city residence, G+3 building.

2.3 Aeration

Treatment unit's aeration, filtration and chlorination were adopted. Aeration increases the DO levels, avoids foul gases and makes user to feel comfortable. For aeration, an aquarium pump of capacity 2.5 W is used in a tank of size $25 \times 25 \times 20$ cm^3. Initial DO of the sample is 3.2 mg/lit, and the readings were taken for 0 min, 10 min, 20 min, 30 min, 60 min, 90 min and 120 min. Subsequent readings are 3.2 mg/l, 3.6 mg/l, 4.1 mg/l, 4.5 mg/l, 5.01 mg/l, 6.2 mg/l and 6.45 mg/l. It was observed that most of the flocs settled forming a light and large sludge. Figure 1 shows aeration done for maximum time of 120 min.

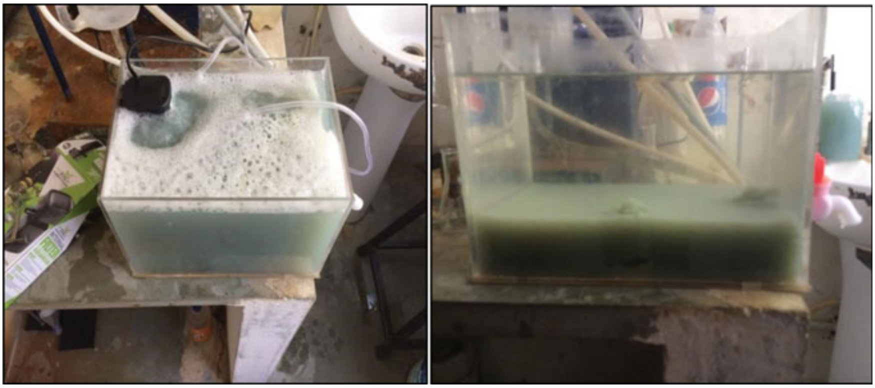

Fig. 1 Aeration before and after treatment

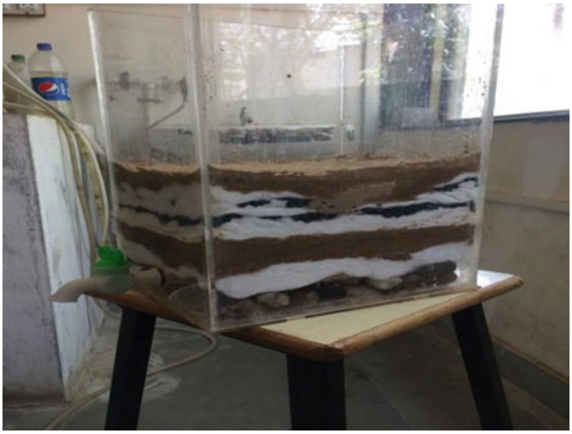

Fig. 2 Rapid sand multimedia filter unit

2.4 Filtration

Filtration helps in removal of dissolved particles. Conventional filters based on rate of filtration are of two types: slow sand filter and rapid sand filter. Rapid sand filter filters faster than the slow sand filter. Rapid sand filter of three layers was constructed. Topmost layers consisting of sand followed by activated carbon layer finally gravel are placed for the support of top layers. Sand of effective diameter D_{10} 0.425 mm is sieved and is prepared by cleaning (separating from any impurities), and next it is oven dried for 24 h at 105 °C. The sand layer consisting of 2 cm thickness followed by activated carbon for more adsorption of dissolved particles and removal of bacteria can be processed by crushing the coal available from the market made of wood, washed with distilled water and then crushed to get fines 2 mm size. Thickness of activated carbon layer is 2 cm. These fines are bound using $CaCl_2$ to make layer of carbon. Gravel of size 5 cm is washed with distilled water and oven dried for 24 h @ 105 °C. The whole set-up is arranged in a plastic tank of size $25 \times 20 \times 35$ cm^3. Figure 2 shows rapid sand multimedia filter unit. Multimedia filters use different sand layers of different sizes here, and a layer of charcoal acts as an adsorbent.

3 Results and Discussions

Chemical and physical characteristics of grey water initial and after treatment are shown in Table 2. Detention time of 90 mins for aeration is chosen as optimum time as it can be reduced to 60 min also if desired. Aeration not only decreased foulness. As seen in the figure, aeration promoted in agglomeration of the particles made the sludge light and large. Air itself acted as a coagulant. Grey water consisting of both positively charged and negatively charged ions got activated by rapid agitation using external energy source, and aeration increased the oxygen levels and could have

Table 2 Test results before and after recycling

S No.	Physical and chemical parameters	Before treatment	After treatment
1	Turbidity	78 NTU	12 NTU
2	Temperature	28 °C	22 °C
3	pH	7.6	7.3
4	Conductivity	83	25
5	TDS	584.6 mg/l	143 mg/l
6	DO	3.2 mg/lit	6.2 mg/lit
7	BOD5	66 mg/l	36 mg/l
8	COD	527 mg/l	97 mg/l

increased oxidation of some compounds resulted in flocculation. Theory behind could be ionic layer compression, and this has to be studied further. Aeration has helped in coagulation which further helped the filter from clogging and increased the filter lifetime. The initial BOD5 and COD concentrations were 66 and 527 mg/L and show that grey water is a high strength grey water having BOD_5: COD was 0.125 which was not easily biodegradable and thus requires combination of both straining and biological treatment. Straining was done using dual media filter. Filtration helps in great reduction in COD. Biological treatment should be further proceeded in order to avoid bacterial population. Turbidity 78–12 NTU and suspended solids of the sample are considerably reduced which may not choke the pipes. Filtration not only removes total suspended particles resulting in reducing COD also removes many pathogenic organisms. Filter should be cleaned when the filtering capacity has reduced to a prefixed value and when the filter bed got exhausted by maximum absorption. The pilot plant filter has obtained a rate of filtration of 465 $l/h/m^2$ considering a peak flow of 5.16 l with a filtered flow 3.88 l in a time of 10 min. The filter ROF can be further increased by increasing the sand size. Pilot plant revealed that filter has good capacity of ROF similar to rapid sand filter which is very helpful in time saving. Table 2 helps in understanding the importance of treatment and effectiveness of aeration and filtration.

4 Conclusions

Pilot studies have revealed that recycled water has sufficient capacity to treat grey water which can be easily used for the flushing. The water also showed markable increase in DO (3.2–6.2 mg/l), BOD5 (66–36 mg/l) and COD (527–97 mg/l). The project is to be added with the additional plumbing, extra one more pipe line is required for pumping recycled grey water and two tanks for storage of grey water and recycled grey water which is shown in Fig. 3 below drawn in AUTOCAD.

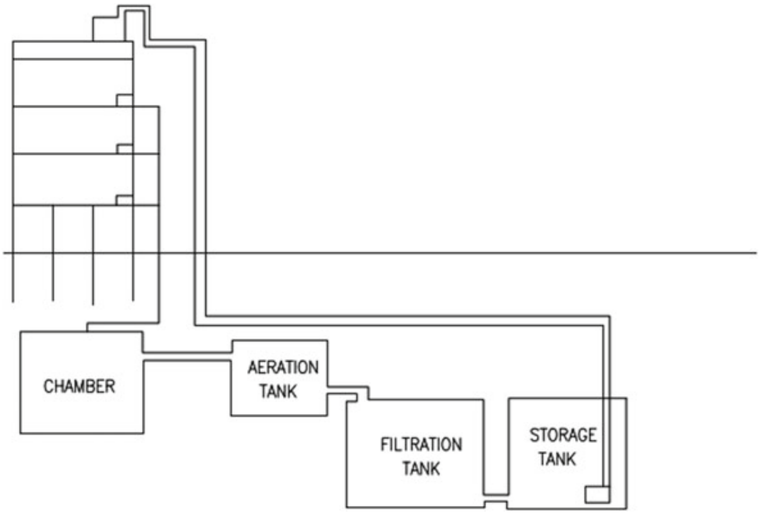

Fig. 3 Layout of decentralized grey water system

Future Scope

The following recommendations/limitations have to be concentrated more to make the system more reliable:

- Maintenance is a very big problem in a large scale, i.e. storing of grey water for long duration will produce foul gases which can be solved by providing intermediate aeration by automatic mechanical system.
- This intermediate aeration can be provided by brakes and mixing system, i.e. when vehicles apply brakes, it causes agitation in the aeration tank.
- Filters sand layers have to be checked in order to maintain non-choking.
- In India, one pipe system is followed, and this system is more adaptable when two pipe system is available. In two pipe system, grey water can be directly collected in the chamber.

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