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Feasibility of Greywater Treatment with River Sand and Polypropylene Pall Rings as Filter Media

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Abstract: ***There is an increase in scarcity of water with rapid population increase in urban areas giving reason for concern and the need for appropriate water management practices. Greywater recycling is emerging as a new trend in water management practices. Initiatives by the Urban Local Bodies (ULBs) have resulted in attempting the greywater recycling in urban areas, flats and apartments and also in individual houses. A rational design is not available for greywater recycling unlike domestic wastewater. Hence, a study was taken in National Institute of Engineering (NIE), Mysuru campus to evaluate the feasibility of treating greywater using river sand and PPPR. The methodology involved designing, fabricating and installing a greywater treatment model in NIE campus. Greywater treatment system installed in NIE campus consisted of anaerobic and aerobic treatment units. The system was monitored over a period of time to check the performance. The sampling of greywater was done weekly and the samples were analyzed for different water quality parameters like pH, TDS, TSS, BOD, COD, turbidity and nutrients. The greywater treatment system with river sand and PPPR as anaerobic and aerobic filter media was effective in removing the turbidity, TSS, COD, BOD and nutrients from the greywater samples to significant extent. It has shown moderate efficiency in removing TDS compared to other parameters.***

Index Terms*: Biochemical Oxygen Demand, Chemical Oxygen Demand, Polypropylene Pall Rings, River Bed Pebbles, Total Dissolved Solids and Total Suspended Solids.*

I. INTRODUCTION

Water is an imperative constituent of regular day to day existence. It is used straight forwardly in domestic consumption, industries, urban endeavors, and agriculture. The health and diversity of ecosystem depends upon water. Everywhere throughout the nation, the reusing of wastewater has been done for a wide number of reasons that incorporate; to expand the accessibility of water, to moderate water shortage and dry spell, to give protection for public health and environment.

A. Residential Wastewater Concept and Classifications

Residential wastewater is a type of wastewater that is generated within the household due to human activities. They are a) Black water and b) Greywater.

a) Black water

Black water is the wastewater that is generated from urinals and toilet fixtures. It is exceedingly sullied with broken down synthetic compounds and undigested food. The conventional treatment is necessary to reuse black water.

b) Greywater

Greywater contributes highest percentage of the overall amount of residential wastewater [2]. Greywater is generated from laundry machines, showers, kitchen sinks, bathtubs, or whatever other water which has been utilized at residence, except from toilets and urinals. Greywater may likewise contain pathogens, soap, detergent residue, bacteria, metals, nutrients, oil and grease, and solids [3]. Partition of greywater and black water, and onsite greywater treatment is a feasible alternative to advance its utilization for toilet flushing as well as planting particularly in arid regions [1]. It gets its name from its shading, as neither being heavily contaminated nor fresh and also due to its cloudy appearance. It is less sullied and distinctively treated compared to black water. It is normally appropriate for reuse. Classification of residential wastewater and sources of greywater is shown in Fig 1. and Fig 2.

Fig 1. Classification of Residential Wastewater

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Fig 2. Sources of Greywater

B. Advantages of Greywater Recycling

The advantages of recycling greywater are,

- Recycling of greywater saves water and decreases the stress on amount of fresh and good quality potable water.
- Greywater is a desirable source for plant growth and landscaping, particularly in arid regions.
- On-site treatment of greywater minimises the wastewater quantity that has to be diverted to sewerage or septic treatment tanks.
- The main benefit of recycled greywater is, it comprised with huge volume and less organic content.
- Recycled greywater can be made as a good fertilizer or nutrient source for irrigation, since it is rich in nitrogen, phosphorous and potassium.
- Greywater treatment system is well suitable for small scale and can be best implemented in urban households.
- Recycled greywater reduces the significant amount of nutrients and other poisonous contaminants entering the waterways.
- It reduces the dependency on surface and groundwater sources.

C. Greywater Treatment Techniques

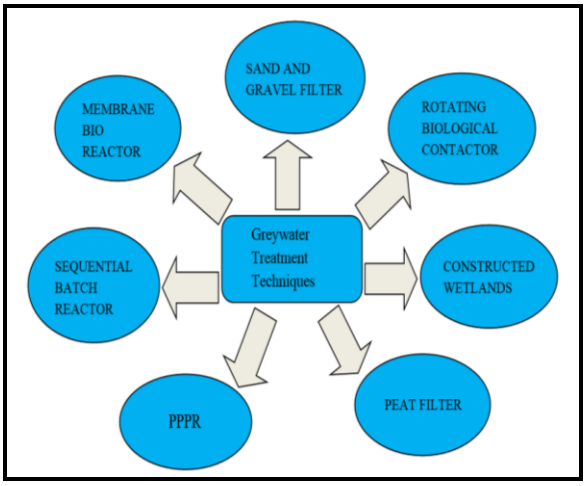

Fig 3. Common Greywater Treatment Techniques

There are wide varieties of greywater treatment techniques available which differ in cost, complexity and performance. The greywater treatment techniques have been summarized in the Fig 3. These techniques can be adopted either for a single household or for a large scale reuse.

D. PPPR

PPPR as the name itself indicating that it is made of polypropylene material. It is of U tube like structures, hence called as pall rings. These rings are characterised by large surface area, large volume of voids, uniform liquid contact and good chemical resistance. It can be placed in various forms like horizontal, vertical and zigzag. When the water trickles through the PPPR media, it results in the better treatment efficiency. Since aerobic conditions are maintained in the media wastewater will be treated with high efficiency (Fig 4.).

Fig 4. Polypropylene Pall Rings (Synthetic Material)

E. Objectives

The study has been taken up with the following objectives:

a) To study the existing methodologies for greywater treatment and to plan an appropriate treatment plant for urban households.

b) To design and fabricate a laboratory scale greywater treatment plant.

c) To study performance and efficiency of the greywater treatment plant for organic and hydraulic loadings.

d) To develop an appropriate approach for greywater recycling/reuse in urban households.

F. Scope of the Present Study

Scope of the study includes designing, fabricating and installing a greywater treatment plant in NIE campus and to study its performance over a period of time for various hydraulic and organic loadings, and to suggest a typical greywater recycling plant for urban households with suitable filter media.

II MATERIALS AND METHODOLOGY

A. Design of Greywater Treatment System

a) Anaerobic unit

Anaerobic treatment unit are used to treat high strength greywater. Initially, the BOD of greywater is assumed to be 150 mg/l. While designing the anaerobic treatment unit the efficiency of system was assumed to be around 70% with the detention time of 24 hours. In the present study the anaerobic treatment unit was designed for a hydraulic detention period of 24 hours.

Therefore, volume of anaerobic unit was calculated for a detention period of 24 hours. The inflow to the anaerobic treatment unit was arranged through sub surface perforated pipes.

b) Aerobic unit

Aerobic treatment unit was designed to reduce the volume of greywater pollutants that are treated through the anaerobic unit and make it suitable for subsequent use. The designing of aerobic unit was based on Eckenfelder's equation. Considering the influent BOD of greywater as 45 mg/l and effluent BOD of the greywater as 10 mg/l, the efficiency of the system was calculated. The lab scale model and working model of greywater treatment system is shown in Fig 5. And Fig 6.

B. Selection of Filter Materials

In the proposed greywater treatment model, the top layer of anaerobic unit which is below the perforated inlet pipe consists of two layers of aggregates of size 12.5 mm and 10 mm respectively. The size of the river bed pebbles which is used for packing the perforated pipes was selected in such a manner that, its size is larger than the holes or perforations to prevent migration of river sand into the pipe and to avoid clogging.

Then it is followed by river sand which is locally available and also has potential to filter suspended, floating, organic and inorganic mass. This layer accelerates the growth of micro-organisms which helps in removal of organic matter from greywater.

The aerobic unit is filled with synthetic material that is polypropylene pall rings of size 25 mm diameter. This size of polypropylene pall rings was selected based on the circulation of air through these rings and large surface area, which results in maintaining the aerobic condition. The selection of the filter medium is shown in Table 1.

Table 1. Selection of Filter Materials

Sl. No.	Treatment Unit	Filter Media	Size (mm)
1	Anaerobic	RBP-1	12.5
		RBP-2	10
		River Sand	2 to 0.425
2	Aerobic	PPPR	25

C. Tests Conducted on River Sand

a) Gradation test was done in order to find effective size and uniformity co-efficient of the river sand. It was found to be 2.125 which represents that the sand is uniformly distributed. D_{60}/D_{10} is suggested because this ratio covers the half of the size of sand. The uniformly distributed sand contains high percent of void space and avoids clogging. Hence the uniformly distributed sand passing through 2 mm and retained on 425µ IS Sieve was taken for further analysis.

b) Permeability test was conducted on the selected river sand sample after gradation test. The average permeability was found to be 0.1315 mm/sec which represents that the sand is clean and has good drainage condition. Since the sand permeability was good, the sand passing through 2 mm and retained on 425 µ was taken as filter media for treatment of greywater.

D. Collection of Greywater Samples

Greywater samples were collected from NIE canteen, especially from the kitchen. The greywater samples were collected twice a day and loaded to the system. The raw and treated greywater samples from anaerobic and aerobic treatment units were collected once in a week for testing. The influent and effluent greywater samples were taken to the Environmental Engineering Laboratory and were analyzed for various characteristics using standard procedure. Then efficiencies of the greywater treatment plant for different organic loadings were studied and performance of the system was evaluated. Based on performance of the laboratory scale model, a typical greywater treatment plant was suggested to treat the greywater from urban households.

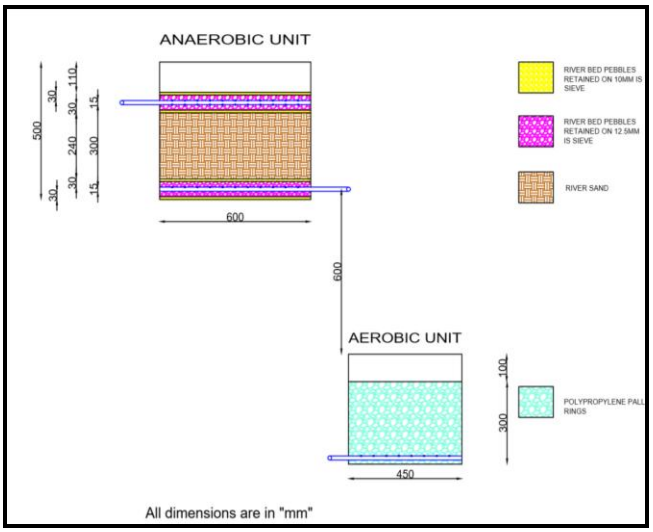

Fig 5. Lab scale Model of Greywater Treatment System

Fig 6. Working Model of Greywater Treatment System

III RESULTS AND DISCUSSIONS

Table. 2 shows the overall efficiency of the greywater treatment system. Hence, treated greywater is having a potential to be reused for gardening and toilet flushing purposes. The treated greywater used for gardening may result in good greenery around the house enhancing aesthetics and hence becomes a desirable source for plant growth. The recycled greywater from this system also helps in conserving freshwater and reduces the stress on amount of fresh and good quality drinking water. For a family of five members, which generates around 500 liters of greywater a scaled up prototype can be used in urban households to treat and reuse greywater. The design values of treatment units to treat greywater with capacity of 500 liters/day is shown in the below sections (Fig 7).

Table 2. Overall Efficiency of the Greywater Treatment System

Parameters	Raw Sample	Treated Sample	Efficiency (%)
pH	6.8	6.7	-
TDS, (mg/L)	1160	390	66
TSS, (mg/L)	643	65	90
Turbidity, (FAU)	2006	77	96
BOD_5, (mg/L)	2675	307	89
COD, (mg/L)	2670	150	94
Sulphates, (mg/L)	6.2	0	100
Nitrates, (mg/L)	6.9	0	100
Phosphates, (mg/L)	17	0	100

Size of anaerobic unit (1200 × 600 × 1100) mm.

Aerobic unit (800 × 400 ×1100) mm.

Diversion tank and collection tank (1200 × 600 × 1100) mm.

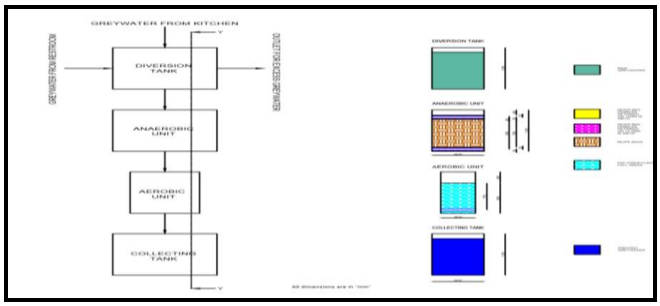

Fig 7. Cross-section of the Proposed Greywater Treatment Plant of 500L Capacity

IV. CONCLUSIONS

[1] The greywater treatment system developed in the Institute is found to be efficient in treating high strength greywater generated from the Institute canteen kitchen.

[2] The greywater treatment system developed in the Institute is found to be efficient in removing BOD and COD by 90% and nutrients (Sulphates, nitrates and phosphates) by 100%.

[3] Although the anaerobic and aerobic treatment units were found to be working with high efficiency the treated greywater was not found to be meeting pollution control board standards of disposing wastewater to natural water bodies.

[4] The system has an overall efficiency of 90% in removing pollutants from greywater. Hence the treated greywater can be used for gardening and flushing toilets. But further treatment is required for reuse in other purposes in urban households. Based on the studies carried out on laboratory scale model, a treatment system has been proposed to treat 500 liters of greywater per day from urban households.

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