Comparison of Polyurethane Filter with Natural Filter of Laterite and Gravel for Grey Water Treatment

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Abstract— *Grey water recycling is now accepted as a sustainable solution to the general increase of the pure water demand, shortage of water and for protection of the environment. In this work a laboratory scale grey water treatment system with filters containing polyurethane and laterite-gravel were used as the filter medias was studied. Polyurethanes are resins with sponge like cellular structure and can be effectively used as biological media of the filter. Laterite is a weathered rock readily available in several parts of the country. In the experiment, the filter medias were arranged horizontally and vertically and the performance efficiencies of both the arrangements were compared. From the experimental study it was observed that polyurethane can act as an efficient filter media and is satisfactory according to bio film formations and removal performance. By analyzing the filters, maximum removal efficiency was obtained for the horizontal polyurethane filter for a contact time of 1hr. The optimum BOD and COD removal efficiencies were obtained as 85.4% and 85.75% respectively, and the total solids removal was 83% and turbidity removal was 98%.*

Keywords— Grey Water, Black Water, Polyurethanes, Laterite Soil, Aerobic Treatment, Filtration

I. INTRODUCTION

Water is an important resource for the survival of life and now a days it becoming scarce in the world. International Water Management Institute predicts that in India alone, the one person in three will live in conditions of absolute water scarcity by 2025. It is therefore necessary to reduce surface and ground water use in all fields of consumption, to substitute pure water with alternative water resources and to optimize efficiency of water usage through reuse and recycling options. These alternative resources include conservation of rainwater and grey water [1].

With increasing global population, the difference between the demand and supply for water is increasing and is reaching such a level that in some parts of the world it is posing a threat to life existence. Alternative water sources can potentially save significant amounts of fresh water. Grey water is one of the alternative sources of water. It is an opportunity, to refocused on one of the technique to recycle water through the reuse of grey water by economical and an efficient way. Grey water is the used water coming from kitchen utensils, washing clothes, shower or bath and other domestic purposes and without any excreta. Grey water is also one of the major pollution sources, which is discharged from residential and commercial areas into the water bodies without any treatment. The quantity of grey water changes with the quantity of water supplied and certain local practices, such as whether bathing and clothes washing is done at the water source. There are a lot of ways to treat grey water so that it can be reused [2].

Grey water is different from black water in the amount and composition of its chemical and biological contaminants. Dish, shower, sink, and laundry water comprises of about 50-80% of waste water generated in the residences [3]. Grey water may contain traces of dirt, food components, grease, hair, particles and certain household cleaning products. Sources of grey water include, e.g. sinks, showers, bath tubs, washing machines or dish washers. As grey water contains less amount of pathogens than the normal wastewater, it is generally safer to handle and easier to treat and reuse onsite for toilet flushing, landscaping or crop irrigation, gardening, construction and other non potable purposes [4].

Grey water is generally produced from households and it is a reflection of the household activities, also its characteristics and composition are dependent on living standards, social and cultural habits, number of members in the household and the usage of household chemicals. Grey water from bathtubs, showers and washbasins are considered as the source of least polluted grey water. The mean grey water contribution to the total organic load amounts to about 40 – 50%.Grey water composition varies in each households, and is depends on the personal habits of residents and the products used in the home, reflecting the lifestyle of the residents and the choice of household chemicals for laundry, bathing, etc.

Grey water composition also varies according to source. The first source is grey water originates from bathroom, such as water used in washing of hands or body parts and bathing generates around 50- 60% of total grey water. It is considered to be the least contaminated type of grey water. Common chemical contaminants include soap, shampoo, hair colouring agents, toothpaste and household cleaning products. It may contain some faecal contamination through body washing. The second source is grey water from kitchen sinks, and it contributes about 10% of the total grey water. It is contaminated mainly with food particles, oils, fats etc. It readily promotes and supports the growth of microorganisms. The third source is grey water from washing of clothes, water used in washing generates around 25-35% of total grey water. Wastewater from the cloth washing varies in quality from wash water to rinse water.

Grey water treatment is a permissible method for reuse; treatment methods vary based on biological and chemical characteristics and intended use of treated grey water. Mainly this variation in chemical and microbial quality of grey water depends on source types. Grey water recycling saves water and reduces the amounts of fresh and pure drinking water by substituting the water demand not intended for drinking. On site grey water treatment minimize the volume of wastewater that must be diverted to more costly sewage and septic treatments. It is a valuable resource for landscaping and gardening especially in arid climates. It contains one-tenth of nitrogen content of black water of which half of it is organic and easily filtered and removed by biological uptake in plants. It is also rich in phosphorous, potassium, and nitrogen, making it a good nutrient or fertilizer source for crop irrigation. The concept of wastewater recycling has been developed and different benefits have arisen due to the recycled water.

II. OBJECTIVES

The objectives of this study were

- To assess the current knowledge of pollutant present in household grey water and the suitability of filtration technologies for their removal.
- To evaluate the efficiency of filtration by using the polyurethane filter media.
- To compare the efficiency of horizontal and vertical alignment of filter media in the filters
- To compare the efficiency of polyurethane with natural filter media made of laterite soil and gravel.

III. MATERIALS AND METHODS

A. Polyurethane Media

Foamed plastics are resins with a sponge-like cellular structure. They usually contain a dispersed gaseous phase encapsulated by solid matrix. The cell structure and permeability are important parameters that describe the suitability of a porous medium for flow through applications and hence a thorough understanding of these parameters for the functionalized polyurethane foam is essential for its end-use. The low permeability of these foams indicates a high pressure drop for any practical water/liquid flow rate [5]. Polyurethane had the characteristics of wear resistance, high specific surface, and being suspended in water. It can be used as biological media of the filter. The foam was provided by the supplier in 0.6m x 1.0m x 1.5m blocks, and it was cut into 1cm sided cubes for the experimental work.

Fig. 1: Polyurethane cubes

Media particles were soaked in cow dung for the biological layer formations and the process is called acclimation. It is the process in which an individual organism adjusts to change in its environment allowing it to maintain performance across a range of environmental conditions. This is done to make proper biological layer formation on the filter media. After the acclimation period, the colour of packed media changed from white to light brown due to the microbial layer formations.

Fig. 2: Polyurethane cubes after acclimation

B. Laterite and Gravel Media

Laterite is a weathered rock available abundantly in several parts of the country. It is therefore a readily available, low cost material. Moreover the operation with the laterite water filter is simple and can be used by rural people also. In India laterite is readily available in plenty, as a large area is covered by laterite. Therefore laterite filter media can be used as an alternative, for the grey water treatment. Moreover the capacity of laterite filter media in suitable experimental conditions is more or less comparable to activated carbon, at least for some solutes. Further the laterite media can be extended for development of a simple household filter [6]. Gravel media paced along with the laterite media for providing better drainage. Uses of Laterite Soil are;

- Agriculture
- Building Blocks
- Road building
- Water supply
- Waste water treatment

Laterite soil and gravel were passed through sieve size 4.75mm and retained on 2.8mm was used as the second filter media. Both the materials were soaked in water for 24 hrs for cleaning.

Fig 3: Laterite Soil Media

Fig. 4: Gravel Media

C. Alum

Alum is crystalline solid commonly used for coagulation process. In this work most common and easily available coagulant, potassium alum (Aluminium Potassium Sulphate) was used for coagulation of grey water.

Fig. 5: Alum

D. Reactor Design and Set Up

Laboratory scale grey water treatment unit was designed for 4.5litre capacity with grey water storage tank, filtration tank and a treated grey water collection tank. A 10 litre capacity plastic bucket was used as the storage tank. The flow rate of feed raw water was controlled by the manual control valve fitted along with grey water tank.

In this experiment horizontal as well as vertical filtration tank were designed. Then horizontal filtration tank having 9 liter capacity and it consist of two compartments each of equal capacity of 4.5 liters. One of the compartments was filled with polyurethane media and second with the laterite along with gravel. The gravel media was provided for getting proper drainage. Both the filter units were operated separately and effluent taken out separately from two different outlets. The compartment filled with polyurethane was provided with an air pump and which was connected to power supply. It is for providing better aeration to the biological formation on the polyurethane filter media. The gravitational force was used for the flow of water from grey water tank to filtration tank and collection tank. The schematic arrangement of experimental set up is shown in figure. Dimension of horizontal filtration tank is 30cm x 20cm x 7.5cm and vertical filtration tank is 30cm x 15cm x 10cm. The designed grey water treatment system contained the operation of filtration with aeration.

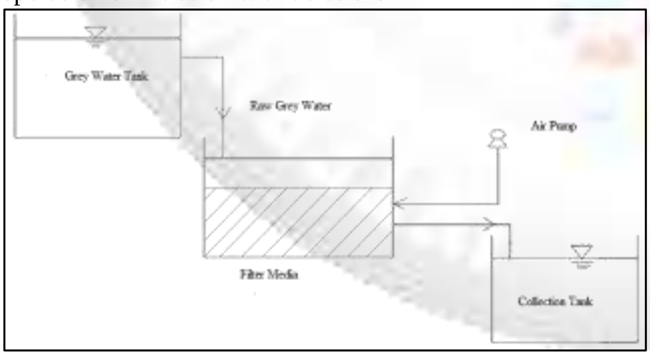

Fig. 6: Schematic diagram of experimental set up

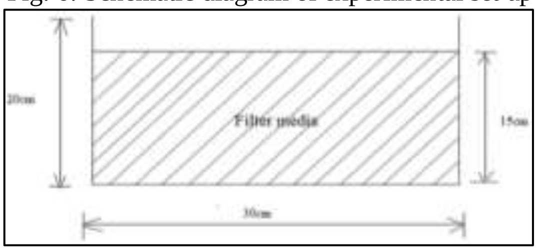

Fig. 7: Depth of filter bed in horizontal filter

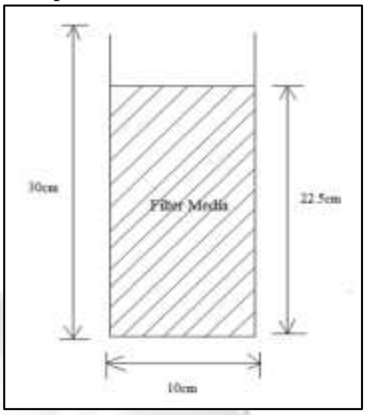

Fig. 8: Depth of filter bed in vertical filter

The filter materials were manually packed in to the filter. During filling they were compacted with glass rod and leveled by manual shaking. Prior to start of the experiment the laterite filter was fed with tap water to wash the filter materials, after which the filters were operated with artificial grey water. The whole laboratory set-up was kept at room temperature. For comparing the horizontal and vertical alignment of filter materials, after working with the horizontal flow tank the vertical column filter with the same capacity was installed instead of the horizontal filtration unit.

E. Preparation of Synthetic Grey Water

Synthetic grey water (SGW) was prepared by using various available materials like cloth washing soap, bathing soap, hair oil, cooking oil, tooth paste and shampoo. Since in India there is no such standard for synthetic grey water preparation, in present work grey water is prepared by taking following standard method suggested by some of the pioneer workers [7]. Following composition of Synthetic grey water was prepared in 5 liters. The constituents, manufacturer and quantity taken are shown in table. The parameters were tested by using standard methods.

Constituents	Manufacturer	Quantity
Soap (Washing)	Rin	4.0gm
Soap (Bathing)	Life boy	4.0gm
Hair oil	Parachute	4.0ml
Cooking oil	Safflola gold	3.0ml
Tooth paste	Colgate	2.18gm
Shampoo	Sun silk	3.0ml
cow dung	-	1.0gm

Table 1: Preparation Synthetic Grey Water

Fig. 9: Prepared Synthetic grey water sample

Sl. No.	Parameters	Value
1	pH	6.6
2	Turbidity (NTU)	554
3	COD (mg/l)	264

4	TDS (mg/l)	563
5	TSS (mg/l)	184
6	BOD5 (mg/l)	192
7	Nitrates (mg/l)	0.67
8	Phosphates (mg/l)	0.012
9	Total solids(mg/l)	747

Table 2: Characteristics of Synthetic Grey Water

F. Flow Rate Optimization

The experimental set up was run at different flow rates for finding out the efficient flow rate for filtration operations. Here three different influent flow rate were given and the characteristics of treated grey water was analysed. Given flow rate were 1.5 ml/min, 3 ml/min and 4.5 ml/min. The results obtained are given the following table. By analyzing the values obtained 3 ml/min is selected as optimum flow rate.

Parameter checked	Value		
	1.5 ml/min	3 ml/min	4.5 ml/min
pH	7.45	7.20	7.50
Turbidity (NTU)	290	172	244
BOD5 (mg/l)	60	34	41
COD (mg/l)	90	50	62

Table 3: Flow Rate Optimization

G. Filtration

The experiment was carried out at laboratory scale process using a poly urethane filter and laterite and gavel filter to treat synthetic grey water. The filter was placed adjacent to the raw grey water tank, and fed with raw grey water. The grey water filtration tank was designed for capacity 4.5 liters. The arrangement of filter media in the horizontal filtration tank is shown in figure. The filter medias were set up both horizontally and vertically and the following figures shows the setup of filtration units.

Fig. 10: Arrangement of Filter Media

Fig. 11: Horizontal Filter

Fig. 12: Vertical Polyurethane Filter

Fig. 13: Vertical laterite filter

H. Coagulation

Coagulation is an essential process in the treatment of both surface water and wastewater. Its application includes removal of dissolved chemical species and turbidity from water via addition of conventional chemical-based coagulants, namely, alum ($AlCl_3$), ferric Chloride ($FeCl_3$), polyaluminium chloride (PAC) etc. Here commonly used coagulant alum was used.

For the coagulation process 500 ml of treated grey water was taken in 5 cylinders each of capacity 1L. In each cylinder different coagulant dosages were added. The dosage varied from 0.2- 1 g (0.2, 0.4, 0.6, 0.8, 1.0) respectively. The coagulation was done using jar test apparatus. The treatment was carried out with a speed of 100 rpm for 30 minutes. After this process the coagulation completed. Then the samples were allowed to settling for 30 minutes and the supernatant filtered using filter paper. The filtered water parameters were analyzed such as pH, turbidity and total solids.

Fig. 14: Coagulating with Jar Apparatus

I. *Sample Analysis*

Samples of treated grey water from the two filter medias were collected after providing different contact times such as 0.5, 1, 1.5 and 2 hrs. After flow rate optimization this various contact times were given. Separate outlets were provided for the two different compartment of filtration tank and effluent samples were taken out separately for analysis. Then samples were analyzed for pH, COD, BOD, turbidity, total solids etc. The tests were performed according to standard methods. Similar to horizontal alignment of filter materials, column filtration was also analysed. The efficiency of reduction of various parameters was calculated using the following equation 1.

$E = (C_{in} - C_{out}) / C_{in} \times 100$ ……………… eq: 1

Where E is the efficiency (%), C_{in} the influent concentration (mg/L) and C_{out} the effluent concentration (mg/L).

IV. RESULTS AND DISCUSSIONS

A. *Performance of horizontal filters*

The synthetic grey water was prepared by using the naturally available materials such as soap, oil, shampoo etc. The prepared synthetic grey water was stored in the storage tank and was fed into the filtration tank by using manually operated control valve. The optimum flow rate of 3 ml/min was given for better performance. The compartment on which polyurethane was filled connected to an air pump for giving better aeration to the growth and working of the biological layer formed on the polyurethane media. The raw water was kept in contact with the filter materials for different contact time such as 0.5, 1, 1.5, and 2 hrs. After this contact times each samples were collected from the effluent port. Samples were taken separately for polyurethane and laterite filter. The samples were tested for finding out the removal efficiency of the filter and the values of different parameters obtained are shown in the following tables.

Parameters	Contact time(hrs)			
	0.5	1	1.5	2
pH	6.75	7.0	7.25	7.36
Turbidity (NTU)	200	155	182	204
BOD (mg/l)	55	28	32	43
COD (mg/l)	82.5	37.6	50	64.4

Table 4: Parameter Analysis of Horizontal Polyurethane Filter

Parameters	Contact time(hrs)			
	0.5	1	1.5	2
pH	6.65	6.9	7.2	7.5
Turbidity (NTU)	224	195	242	280
BOD (mg/l)	96	58	78	84
COD (mg/l)	132	88	94	102

Table 5: Parameter Analysis of Horizontal Laterite Filter

From the table it is observed that maximum parameter reduction was obtained at a contact time of 1hr. After that the parameter values have increased. By comparing the horizontal alignment of polyurethane filter with the laterite filter it is clear that all the parameters checked are reduced better in polyurethane filter than laterite filter. The efficiency of polyurethane filter is calculated is given in the following table.

Parameters	Efficiency at different contact times (%)			
	0.5hr	1hr	1.5hr	2hr
Turbidity	63.8	72	67	63
BOD	71.35	85.4	83.3	77.6
COD	68.75	85.75	81	75.6

Table 6: Efficiency Calculation of Horizontal Polyurethane Filter

In the case of horizontal alignment of polyurethane filter, maximum BOD removal efficiency is obtained as 85.4% and COD removal efficiency is 85.75%. The graphical representation showing the removal efficiency of turbidity, BOD and COD with different contact time of horizontal polyurethane filter are given in the figure below.

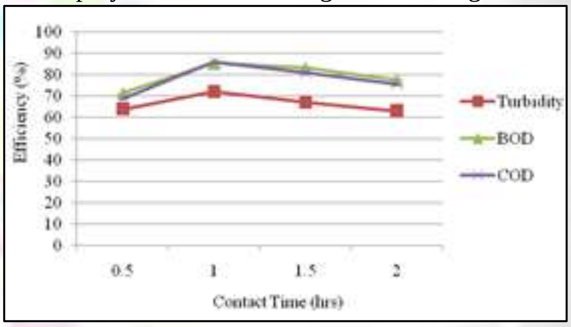

Fig. 15: Efficiency of horizontal polyurethane filter

Parameters	Efficiency at different contact times (%)			
	0.5hr	1hr	1.5hr	2hr
Turbidity	59.6	64.8	56.3	49.5
BOD	50	69.8	59.4	56.25
COD	50	67	64.4	61.3

Table 7: Efficiency Calculation of Horizontal Laterite Filter

In the case of horizontal alignment of laterite filter, maximum BOD removal efficiency is obtained as 69.8% and COD removal efficiency is 67%. The graphical representation of the removal efficiency of turbidity, BOD and COD with different contact time of horizontal laterite filter are given below.

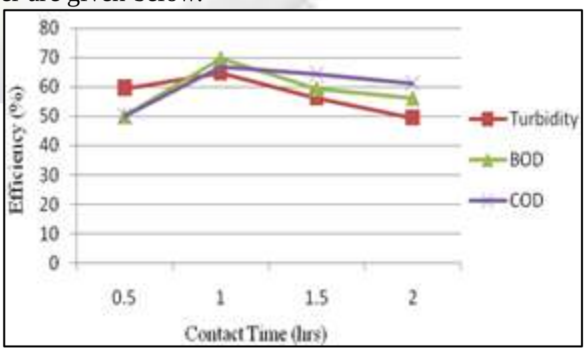

Fig. 16: Efficiency of horizontal laterite filter

B. Performance of Vertical Filters

In the case of vertical alignment of filter materials, column filter having the same capacity of horizontal filtration tank was used. The polyurethane media and the laterite media along with gravel were arranged on the filtration tank separately and parameters removal efficiency was checked. The values of different parameters obtained are shown in the following tables

Parameters	Contact time (hrs)			
	0.5	1	1.5	2
pH	6.68	6.7	6.98	7.50
Turbidity (NTU)	186	198	174	240
BOD (mg/l)	68	44	35	56
COD (mg/l)	104	68	54.6	112

Table 8: Parameter Analysis of Vertical Polyurethane Filter

Parameters	Contact time (hrs)			
	0.5	1	1.5	2
pH	6.8	6.96	7.20	7.45
Turbidity (NTU)	286	244	210	225
BOD (mg/l)	90	76	62	72
COD (mg/l)	135	104	92	106

Table 9: Parameter Analysis of Vertical Laterite Filter

From the tables it is observed that maximum parameter reduction is obtained at a contact time of 1.5hr. After that parameter values have increased. By comparing the vertical alignment of polyurethane filter with the laterite filter it is clear that all the parameters checked were reduced better in polyurethane filter than laterite filter. The efficiency of polyurethane filter was calculated and given in the following table.

Parameters	Efficiency at different contact times (%)			
	0.5hr	1hr	1.5hr	2hr
Turbidity	66.4	64.25	68.6	56.6
BOD	64.5	77	81.7	70
COD	60	74.24	79.3	57.6

Table 10: Efficiency Calculation of Vertical Polyurethane Filter

In the case of vertical alignment of polyurethane filter, maximum BOD removal efficiency was obtained as 81.7% and COD removal efficiency is 79.3%. The graph showing the removal efficiency of turbidity, BOD and COD with different contact time of vertical polyurethane filter is given below.

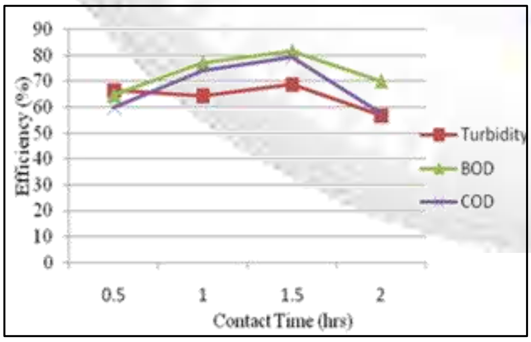

Fig. 17: Efficiency of vertical polyurethane filter

Efficiency of vertical laterite filter is shown in the following table.

Parameters	Efficiency at different contact times (%)			
	0.5hr	1hr	1.5hr	2hr
Turbidity	48.3	55.95	62	59.3
BOD	53.12	60.4	67.7	62.5
COD	48.86	60.6	65.15	59.8

Table 11: Efficiency Calculation of Vertical Laterite Filter

In the case of vertical alignment of laterite filter maximum BOD removal efficiency was obtained as 67.7% and COD removal efficiency is 65.15%. The graph showing the removal efficiency of turbidity, BOD and COD with different contact time of vertical laterite filter is given below in figure.

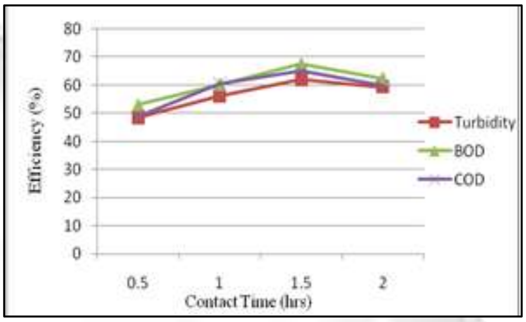

Fig. 18: Efficiency of vertical laterite filter

By analyzing the different filters, maximum removal efficiency was obtained at the horizontal polyurethane filter compared to other filters and arrangements. The optimum BOD and COD removal efficiencies were obtained about 85% and turbidity removal was above 70%. Better results were obtained in the horizontal polyurethane filter for a contact time of 1hr. All the parameters were tested for this sample and the values obtained are shown in table

Sl. No.	Parameters	Value
1	pH	7
2	Turbidity (NTU)	155
3	COD (mg/l)	37.6
4	TDS (mg/l)	500
5	TSS (mg/l)	150
6	BOD_5 (mg/l)	28
7	Nitrates (mg/l)	0.30
8	Phosphates (mg/l)	0.01
9	Total solids(mg/l)	650

Table 12: Characteristics of Treated Grey Water

C. Coagulated effluent characteristics

From the treatment of grey water by using poly urethane filter maximum parameter removal was obtained. But the major drawback in this case is turbidity removal. It was obtained as about 70%. This is due to the presence of solids in treated water. It can be avoided by treating the water with a suitable coagulant. The treated sample which shows maximum removal was taken for coagulation. Here alum was taken as the coagulant and the results obtained as shown in table.

Dosage (gms)	pH	Turbidity (NTU)	Total solids (mg/l)
0.2	7.48	8	160
0.4	7.30	5	130
0.6	7.27	3	110
0.8	7.40	7	140
1.0	7.45	12	180

Table 13: Characteristics of Coagulated Water

More than 90% of removal efficiency was obtained for turbidity after coagulation. But for 0.6 gm dosage high removal was obtained and, after that the parameters goes on increasing so 0.6 gm dosage was considered as the optimum level. At 0.6 g dosage, 98% of turbidity removal was obtained and 83% of TS removal efficiency was obtained. The graph showing removal efficiency is shown in the figure.

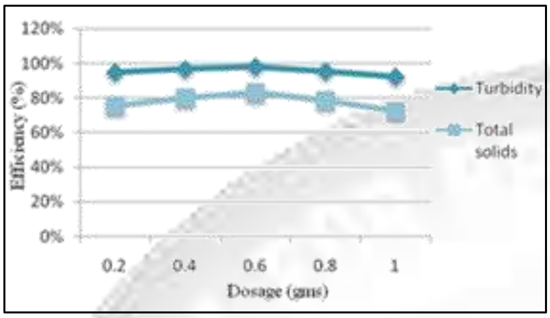

Fig. 19: Removal efficiency after coagulation

D. Discussions

Foam performed as typical bio filter, i.e. it needed a start-up period to develop a bio film with sufficient capacity to degrade and consume the organic matter. The structure of the foam, such that which is characterized by closely connected pores that form continuous paths for water flow. It led to a rapid flow of liquid through the foam immediately after feeding filters with grey water. This in turn led to a limited bio film formation, which was observed to be present mainly in the lower part of the filter. The limited distribution of the bio film most likely restricted the degradation of organic matter. Moreover, high BOD_5 levels were measured towards the end of the experiment in the effluent from the foam filter, probably due to sloughing of biofilm material from the lower surface of filter and breakthrough of organic matter. The polyurethane foam cubes achieved about 85% reduction in BOD and COD during 1hr of contact time.

In the case of biological filtration of grey water aerobic decomposition of organic matter takes place. Air is provided from bottom, so there is no clogging occurs on the filter. After a particular contact time removal efficiency of all the tested parameter were reduced and this may be due to the lower activity of biological layer. Here the micro-organisms on the biological layer consume the organic matter as their food initially at a higher rate. The biological activity is maximum at 1hr contact time in horizontal filter and it is maximum at 1.5hr contact time in the case of vertical filter. Therefore at these contact times maximum removal efficiency is obtained. After that time performance of micro-organism goes on reducing and efficiency also reduces.

By analyzing the results it is understand that the turbidity removal is less in both the horizontal as well as vertical filters. This is because of the presence of dissolved solids in the treated grey water. This is solved by the coagulation technique used after the filtration treatment. And 98% turbidity removal was obtained.

E. Suitability of treated grey water for reuse

The values of different parameters obtained after filtration and coagulation is as follows in table and the standards for grey water reuse were suggested by the central pollution control board (CPCB), are also presented.

Sl. No	Parameters	Value
1	pH	7.27
2	Turbidity (NTU)	3
3	COD (mg/l)	37.6
4	BOD_5 (mg/l)	28
5	Nitrates (mg/l)	0.30
6	Phosphates (mg/l)	0.01
7	Total solids(mg/l)	110

Table 14: Characteristics of Treated Water

	pH	BOD_5 (mg/L)	Turbidity (NTU)	SS (mg/L)	COD (mg/L)
On Land for Irrigation (Is:3307, 1974)	5.5-9	100	-	200	-
Into Inland Surface Water (Is:2490, 1974)	5.5-9	30	-	100	250
Into Public Sewers (Is:3306, 1974)	5.5-9	350	-	600	-

Table 15: CPCB- India (2008) Water Reuse Standards

By comparing the results obtained with the standards of CPCB- India (2008), the treated water can be used for irrigation, and can be discharge in to the surface water or to the public sewers. In the case of pH of treated grey water, it was within the standard range. The optimum value obtained for pH was 7.27, and it was between the limit of 5.5-9. In the case of turbidity, the value obtained was 3 NTU. In CPCB there is no such standard for turbidity. The value obtained for BOD_5 after treatment was obtained as 28 mg/l, and from the standards it can be used for irrigation and can be discharge in to the surface water or to the public sewers. In the case of COD the value obtained was 37.6 mg/l, and is within the range of 250 mg/l.

V. Conclusion

The experiment with polyurethane as the media in the filter is satisfactory according to biofilm formations and removal performance. The present study demonstrated the treatment of residential waste water called grey by using polyurethane filter in horizontal as well as vertical alignment, and was compared with natural filter of laterite and gravel. Based on finding of this study, this treatment technology by using the polyurethane filter media can be considered as a viable alternative. Horizontal alignment of poly urethane media shows better performance, while comparing with other filters. The optimum BOD removal was obtained as 85.4%, optimum COD removal was 85.75%, total solids removal was 83% and turbidity removal was 98%. By comparing with CPCB standards it was observed that the treated grey water can be used for irrigation and can be discharge in to the surface water or to the public sewers.

However, future work necessary for clogging studies and microbial kinetic studies in the grey water filter.

Acknowledgment

I would like to thank UKF College of Engineering and Technology for this opportunity and I would also express my gratitude towards Mrs. Preeja Prameelan and Dr. K Mophin Kani for their support.

REFERENCES

[1] Friedler E., (2004) Quality of individual domestic grey water streams and its implication for onsite treatment and reuse possibilities, Environmental Technology, 25, 997-1008.

[2] Eriksson E., Auffarth K., Henze M., Ledin A., (2002) Formulation of a synthetic grey water to evaluate the performances of on-site grey water recycling technologies, Urban Water, 4, 85-104.

[3] Intizar Hussain, Liqa Raschid, Munir A. Hanjra, Fuard Marikar and Wim Vander Hoek, (2002) Wastewater use in agriculture: Review of impact and methodological issues in valuing impacts, working paper 37, Colombo, Sri Lanka, International water management institute 1-3. Available: https://books.google.co.in/books?isbn=1522510478.

[4] P.S. Anjaly, (2013) Enhancement of efficiency of treatment of grey water by down flow hanging sponge (DHS) biotower, International Journal of Engineering Research and science and Technology, 2(4), 13-20.

[5] Subhashini Gunashekar, Krishna M Pillai and Benjamin C., (2015) Liquid flow in polyurethane foams for filtration applications: a study on their characterization and permeability estimation, Journal of porous materials, 22, 749-759.

[6] Asit R. Sarkar, Jawarlal Goswami, Aparna Banerjee, Partha P. Pramanick and Mitali Sarkar, (2001) Laterite as a Filter Media for Reducing Some Priority Inorganic Contaminants in Water, University of Kalyani, India, Available: https://www.researchgate.net/publication/237440915

[7] Fanny Houlier, Anthony Masse, Pascal Jaouen,Abdel Lakel,Claire Gerente, and Catherine F.,(2010) Formulation of Synthetic Grey water as an evaluation for wastewater recycling technologies, Environmental Technology, 31, 215-223.

[8] Jiang Chundong, Xu Zhi, Fei Quingzhi and Guo Haiyan, (2012) Treatment of synthetic waste water in a pre-denitrification biofilm reactor packed with polyurethane media, Energy Procedia, 16, 1642-1649.

[9] Abeer albalawneh and Sun-kuo chang, (2015) Review of the greywater and proposed greywater recycling scheme for agricultural irrigation reuses, International journal of research, 3(12), 16-35.

[10] Amr M. abdel Kader, (2013) Studying the efficiency of grey water treatment by using rotating biological contractors system, Journal of King Saud University - Engineering Sciences, 25 (2), 89–95.

[11] Gupta S.K., and Deshpande R.D., (2004) Water for India in 2050: first order assessment of available options, Current science, 86(9), 1216- 1224.

[12] H. Al-Hamaiedeh, (2010) Effect of treated grey water reuse in irrigation on soil and plants, Desalination, 256, 115–119.

[13] J. S. Almeida, N. Rocha, and M. R. Franco Junior, (2013) Treating Domestic Grey water and Expectations to be Reused, American Journal of Environmental Engineering, 3(4), 195-198.

[14] J.S. Lambe, R.S. Chougule, (2000) Greywater - Treatment and Reuse, IOSR Journal of Mechanical and Civil Engineering, 20-26.

[15] Jefferson B., Palmer A., Jeffrey P., Stuetz R., and Judd S., (2004) Grey water characterization and its impact on the selection and operation of technologies for urban reuse, Wat. Sci. Technol., 50, 57-64.