Alinteri J. of Agr. Sci. (2021) 36(2): 01-07
e-ISSN: 2587-2249
info@alinteridergisi.com

http://dergipark.gov.tr/alinterizbd
http://www.alinteridergisi.com/
DOI:10.47059/alinteri/V36I2/AJAS21108

RESEARCH ARTICLE

A Preliminary Investigation on Performance of Multicompartment Sand Filter for Treatment of Grey-Water

Charuta S.Waghmare[1*] • Prajakta Pazare[2] • Khalid S. Ansari[3]

[1*]*Assistant Professor, Department of Civil Engineering, Yeshwantrao Chavan College of Engineering, Nagpur, Maharashtra, India.*
[2]*PG Scholar, Department of Civil Engineering, Yeshwantrao Chavan College of Engineering, Nagpur, Maharashtra, India.*
[3]*Assistant Professor, Department of Civil Engineering, Yeshwantrao Chavan College of Engineering, Nagpur, Maharashtra, India.*

ARTICLE INFO

Article History:
Received: 25.04.2021
Accepted: 02.06.2021
Available Online: 12.07.2021

Keywords:
Synthetic Grey-water
Multicompartment Sand Filter
Chemical Oxygen Demand
Turbidity
Total Suspended Solids

ABSTRACT

Water is the vital natural resource for the survival all biotic species. Demand of water is growing day by day as a result of rapid industrialization, production, and growth in population. As a result, it is necessary to look for the alternatives to reduce our freshwater usage. Grey-water treatment appears to be one of the most promising alternatives. The conventional filtration process with sand as a filter media is considered as a cost effective technique for water and waste water treatment. Amongst the various techniques of filtration, the performance of the Multicompartment Sand Filter, a modified version of a sand filter is examined in this paper in four different experimental setups. It is discovered that this sand filter is effective in removing Chemical Oxygen Demand, Total Suspended Solids and turbidity with percentage removal of *95.94%, 89.72%*% and *64.69%*% respectively. This filter is easy to manage, adaptable, compact and cost effective.

Please cite this paper as follows:
Waghmare, C.S., Pazare, P. and Ansari, K.S. (2021). A Preliminary Investigation on Performance of Multicompartment Sand Filter for Treatment of Grey-Water. *Alinteri Journal of Agriculture Sciences, 36*(2): 01-07. doi: 10.47059/alinteri/V36I2/AJAS21108

Introduction

Water is a precious natural resource which is essential for human existence. Water covers approximately 70% to 80% of the earth, but just three percent of it is fresh water. The amount of freshwater available for human consumption is extremely limited. Grey-water reuse is a key for satisfying domestic and agricultural needs.

Grey-water has a contamination level which is halfway between potable water and waste water. As a result, grey-water has a greater capacity for reuse than wastewater. Grey water accounts for 50% - 70% of household wastewater, Morel A.et al, (2006), Grey Water Reuse in Rural School, (2007) and Jefferson B, et al, (2004).

As a result of population growth and pollution, water is being polluted on regular basis and so the purity of water is deteriorating.

* Corresponding author: Charuta S.Waghmare

According to the World Water Organization (2009), by 2050, two-thirds of the world wide people will face freshwater scarcity, John N.et al.(2017). By 2025, 1.8 billion people around the world may live in regions and countries or territories where water is scarce, and it is possible that two-thirds of the global population may live in water-stressed countries as per report from UNDESA, (2014).

To put an end to a crisis like this, it is important to consider alternatives and methods for conserving freshwater bodies. Grey-water is characterized as any waste water generated in the home, excluding sewage. In other words, according to Amal B Mohan et al.(2016) domestic grey-water is a combination of household waste discharges such as kitchen drains, laundry waste water, and bathtubs.

Grey-water recycling has many benefits explained by Bessy John et al, (2017), including, less pressure on septic tank, less fresh water extraction, ground water recharge, treatment plant facilities, reduced energy usage, increased surface water quality, enhanced crop production, soil fertility, conservation of ground water, preservation of vegetation and land as well as protection of the environment from potential transmission of water based diseases.

Grey-water disposal can be accomplished in a number of ways. Since antiquity, sand filtration has been regarded as one of the most efficient and cost-effective technologies for wastewater and water treatment, Pazare et.al. (2018). The Drawer Compacted Sand Filter (DCSF), also known as Multicompartment Sand Filter (MCSF), first proposed in 2013 by Almoayied Assayed at Centre for Environmental Strategy, University of Surrey, Guildford, Surrey, UK, is a sand filter with a modified configuration. The sand layer is utilized into layers in the given assembly. The thickness of sand layers can be arranged in the range from 5 cm to 10 cm, spread in movable drawers with a spacing of 5 cm to 10 cm, Pazare et al.(2018). Since the drawers are separate and arranged in a specific way, oxygen circulation is also improved, resulting in an aerobic atmosphere with no anoxic conditions and hence no unpleasant odours found buy Assayed A, (2015). This work presents performance of MCSF for different experimental setups.

Materials

A. Gravel

The gravels were obtained from the stock sand brought from a supplier from Bhandara district, Maharashtra, India. The material was sieved according to sieve analysis method to obtain the required effective size (D_{10}) of the gravel which is 4.75 mm. The gravel so obtained was first washed with tap water and then with distilled water and oven dried at 110 ⁰ C. **(Figure 1).**

Figure 1. Gravel, D_{10}=4.75 mm

B. Sand

Sand is an important material as it could remove impurities that are present in grey water on a large extend. In the setup, sand of three different effective sizes that are 2.36 mm, 1.30 mm and 0.6 mm are used. The sand of different effective sizes so obtained is first washed with tap water then with distilled water and oven dried at 110 ⁰ C. **(Figure 2a, 2b, 2c)**

Figure 2a. Sand, D_{10}=2.36 mm

Figure 2b. Sand, D_{10}=1.30mm

Figure 2c. Sand, D_{10}=0.6mm

C. Earthen Clay Pot Pieces

Pieces of broken clay pots, a waste material, were obtained from market and crushed into smaller pieces with the help of Jaw Crusher. After that those pieces are sieved into two different effective size of 2.9 mm and 5.28 mm, then the pieces were washed with tap water and after with distilled water. **(Figure 3a, 3b).**

Figure 3a. Earthen Clay, D_{10}=5.28mm

Figure 3b. Earthen Clay, D_{10}=2.9mm

D. Activated charcoal prepared from Coconut shell

Activated charcoal is a charcoal manufactured to increase its porosity and surface area in order to increase its adsorption capacity by Pazare et al.(2018) and Almoayied Assayed,(2014). In this, the activated charcoal made up of coconut shells is used in granular form used as per Pazare et al.(2018). **(Figure 4)**

Figure 4. Activated Charcoal

Methodology

A. Preparation of Synthetic Grey Water and its Characteristics

The characteristics of grey water collected from households were examined, and then the sample was prepared synthetically; Pazare et al.(2018).The synthetic grey water was prepared by mixing Washing powder(0.16 g/l), Coconut oil(0.1 g/l), Dish washing solution(0.16 g/l), Hand-wash (0.16 g/l), Body wash(0.16 g/l) in 1 lit tap water. The characteristics of synthetically prepared grey-water showed the following concentration of parameters. (**Table 1**).

Table 1. Characteristics of synthetic grey-water

Raw Grey water Characteristics Concentration of components
Chemical Oxygen Demand (mg/l) 240
Total Suspended Solids(mg/l) 78
Total Dissolved Solids(mg/l) 628
Turbidity (NTU) 24.30
pH 8.50
Hardness (mg/l as $CaCO_3$) 168

B. Methodology Adopted for Experimentation

a) Experimental setup of Multicompartment Sand Filter - Two sets of operation using different dimensions of plastic drawers was used in the study.

b) One set of drawer having dimensions of 36 cm x 26 cm x 7 cm (7 nos.) (Pazare etal.2018) as well as other of 29 cm x 24 cm x 6 cm(7 nos.) were placed on the fabricated iron framework. The top mounted drawer was used for uniform distribution of sample of synthetic grey water which flows over the gravel bed. A storage container containing synthetic grey water is placed near the framework.**(Figure 5)**

Figure 5. Multicompartment Sand Filter

c) Experimental Work: - Four sets of operation were carried out in the study. **(Table 2).**

Table 2. Details of Experimental Setups

Drawer Nos.	**Experimental Setup**			
	I	II	III	IV
1	Synthetic Grey Water Distribution			
2	Gravels; D_{10} = 4.75mm	Gravels; D_{10} = 4.75mm	Gravels; D_{10} = 4.75mm	Gravels; D_{10}= 4.75mm
3	Sand; D_{10}= 2.36mm	Sand; D_{10}= 2.36mm	Sand; D_{10}= 2.36mm	Earthen clay pot pieces; D_{10}= 5.23mm
4	Sand; D_{10}= 1.3mm	Sand; D_{10}= 1.3mm	Sand; D_{10}= 1.3mm	Earthen clay pot pieces; D_{10}= 1.3mm
5	Sand ; D_{10}= 0.6mm	Sand ; D_{10}= 0.6mm	Activated charcoal	Activated charcoal
6	Activated charcoal	Activated charcoal	Treated grey water Collection	Treated grey water Collection
7	Treated grey water Collection	Treated grey water Collection	-	-
Depth of media	5 cm each			
Size of Perforations	3 mm			
Number of Perforations	12 Nos.	5 Nos.	5 Nos.	5 Nos.

C. Performance and Study of Operating Conditions

Under standard room temperature, synthetic grey water was distributed on a regular basis in Multicompartment Sand Filter, consisting of different filter media like gravel in the top drawer, sand at the intermediate drawers and activated charcoal in the bottom drawer (Pazare et al.2018).The synthetic grey water in storage container was mixed continuously with the help of a mixer to avoid the settling of suspended solids within the storage container. The mixer works at 100 rpm. The synthetic grey water then is pumped to the bucket placed at the top the distribution drawer with the help of a Hi-speed submersible pump which was installed in the storage container. A constant volume of 275.4 ml was maintained in the distribution trays of dimensions 36 cm x 26 cm x 7 cm as well as in the tray of dimensions 29 cm x 24 cm x 6 cm, the flow of 203.04 ml was constantly maintained. The analysis of treated effluent for Chemical Oxygen Demand, pH, Hardness, Total Suspended Solids, Turbidity, Total Dissolved Solids was then analysed using Standard Methods.

D. Treatment Mechanism in Multicompartment Sand Filter

Pumping of the synthetic grey water into the distribution drawer was carried out using a submersible pump and then the sample was distributed in the drawer number 2 having the gravel layer. The water followed the flow path from drawer number 2 to drawer 3, at a flow rate of 4 lit/hour. The treated effluent was then collected and analysed for different parameters.

RESULTS

1) Observations of Experimental Setup-I

From the observations of the experimental setup - I (**Table 3a**) of drawers size 36 cm x 25.5 cm x 7 cm, it was found that the synthetic grey water filtered through the assembly consisting of Gravel+ Sand +Coconut Shell Activated Charcoal as filter media, significant reduction in chemical oxygen demand as 94-96%, total suspended solids as 80-81% and turbidity reduction as 72-75% was achieved.**(Table 3b),(Figure 6).** There were no significant changes in the pH and no percentage reduction in total dissolved solids and hardness from the setup I.

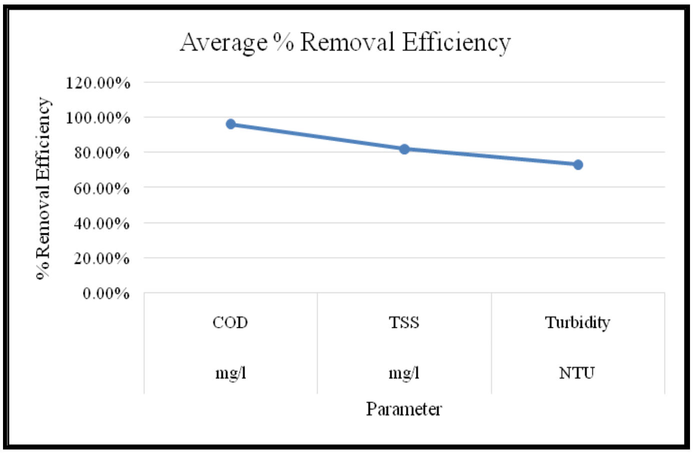

Figure 6. Average % Removal Efficiency of Experimental Setup-I

Table 3a. Experimental Setup-I

Characteristics	Raw Concentration	Treated Concentration	Removal Efficiency in%
COD (mg/l)	240 360 580	10 20 20	95.83% 94.44% 96.55%
TSS(mg/l)	78 82 83	15 15 19	80.76% 81.70% 81.70%
TDS(mg/l)	628.1 905 911	554.4 864 838	11.73 % 4.53 % 4.53 %
Turbidity(NTU)	11.5 22.2 22.2	2.8 6 6	75.65% 72.97% 72.97%
pH	8.5 8.5 8.5	8.5 8.2 8.2	-
Hardness(mg/l as $CaCO_3$)	168 168 156	152 152 144	9.52% 9.52% 7.69%

Table 3b. Average Percentage Removal Efficiency of Experimental Setup-I

Characteristics	% Removal Efficiency			Average % Removal Efficiency
COD (mg/l)	96.55%	94.44%	96.55%	95.85%
TSS (mg/l)	81.70%	81.70%	81.70%	81.70%
Turbidity (NTU)	72.97%	72.97%	72.97%	72.97%

2) Observations of Experimental Setup-II

The results obtained from experimental setup II in which the same filter media as setup I was used but it was placed in different size of drawer (28.8 cm x 23.5 cm x 6 cm). High reduction in chemical oxygen demand was observed along with 65-81% reduction in concentration of total suspended solids. Turbidity reduction of more than 50 % was achieved. **(Table 4a), (Table 4b), (Figure** 7). It was observed that no reduction in total dissolved solids and hardness concentrations. No difference in pH value of the treated greywater was observed.

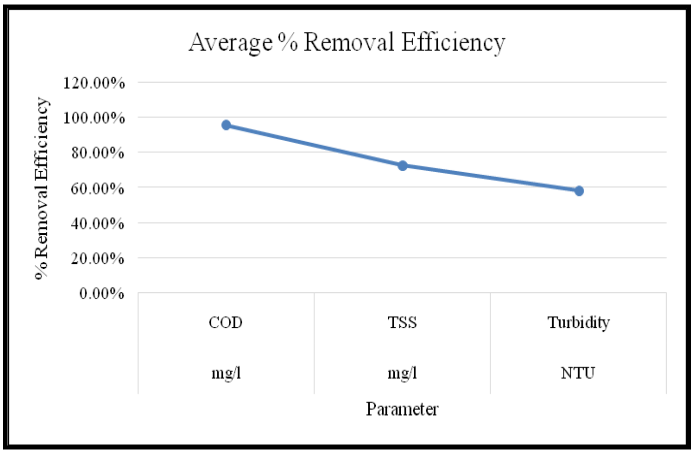

Figure 7. Average % Removal Efficiency of Experimental Setup- II

Table 4a. Experimental Setup-II

Characteristics	Raw Concentration	Treated Concentration	Removal Efficiency in%
COD (mg/l)	240 400 486.15 898.64	0 20 0 114.90	100% 95% 100% 87.21%
TSS(mg/l)	78 140 140 160	17 41 41 53	81.70% 70.71% 70.71% 66.87%
TDS(mg/l)	628.1 1011 1011 1211	554.4 946 946 1133	11.73 % 6.43 % 6.43 % 6.44 %
Turbidity(NTU)	11.5 23.6 23.6 23.5	2.8 11.2 11.2 7.5	75.65% 52.54% 52.54% 52.54%
pH	8.3 8.3 8.5 8.5	8.1 8.1 8.1 8.1	-
Hardness(mg/l as $CaCO_3$)	160 160 180 180	160 160 148 148	No Change No Change 17.77% 17.77%

Table 4b. Average Percentage Removal Efficiency of Experimental Setup-II

Characteristics	% Removal Efficiency				Average % Removal Efficiency
COD (mg/l)	100%	95%	100%	87.21 %	95.55%
TSS (mg/l)	81.70 %	70.71 %	70.71 %	66.87 %	72.49%
Turbidity (NTU)	75.65 %	52.54 %	52.54 %	52.54 %	58.32%

3) Observations of Experimental Setup-III

The filter media used in this assembly was same as that of setup II, except sand of effective size 0.6mm, to check the effect on removal efficiency of the required parameters. From the observations, it was found that major reduction in chemical oxygen demand and total suspended solids takes place with 71-75% reduction in turbidity. No significant removal was seen on other parameters. **(Table 5a) (Table 5b) (Figure 8).**

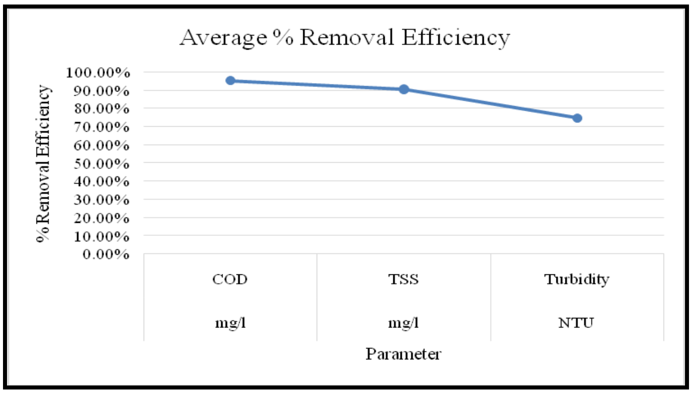

Figure 8. Average % Removal Efficiency of Experimental Setup- III

Table 5a. Experimental Setup-III

Characteristics	Raw Concentration	Treated Concentration	Removal Efficiency in %
COD (mg/l)	246 736.59	0 72.25	100% 90.19%
TSS(mg/l)	75 230	7 23	90.66% 90%
TDS(mg/l)	618.1 889	549.4 849	11.11 % 4.49 %
Turbidity(NTU)	12.5 30.5	2.8 8.6	77.6% 71.80%
pH	8.3 8.2	8.1 7.9	-
Hardness(mg/l as $CaCO_3$)	160 160	160 148	No Change 7.5%

Table 5b. Average Percentage Removal Efficiency of Experimental Setup-III

Characteristics	% Removal Efficiency		Average % Removal Efficiency
COD (mg/l)	100%	90.19%	95.09%
TSS (mg/l)	90.66%	90%	90.33%
Turbidity (NTU)	77.6%	71.80%	74.7%

4) Observations of Experimental Setup-IV

In this assembly, gravel with earthen clay pot pieces was used as the filter media. Significant reduction in the chemical oxygen demand, total suspended solids and turbidity was observed. **(Table 6a) (Table 6b) (Figure 9, Figure 10).**

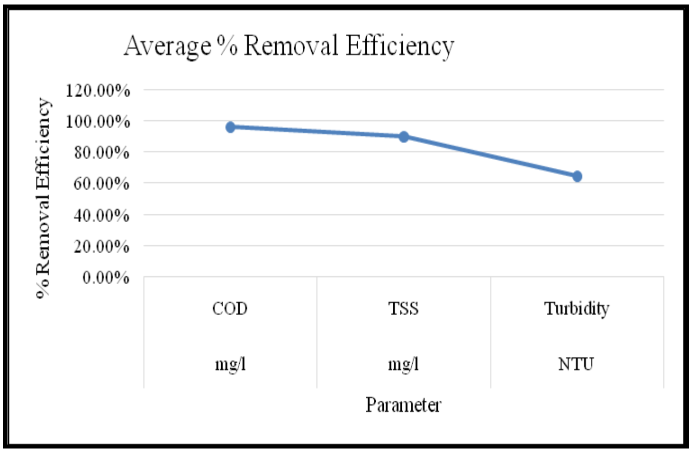

Figure 9. Average % Removal Efficiency of Experimental Setup-IV

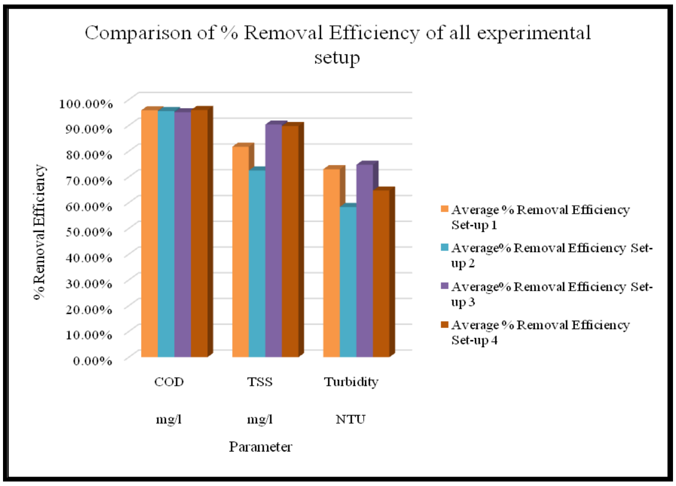

Figure 10. Comparative Graph of Experimental setups

Table 6a. Experimental Setup-IV

Characteristics	Raw Concentration	Treated Concentration	Removal Efficiency in %
COD (mg/l)	253.38 436.06 571.06 636.42	0 0 38.30 60.66	100% 100% 93.29% 90.47%
TSS(mg/l)	78 200 74 74	15 19 5 5	80.76% 90.5% 93.2% 93.2%
TDS(mg/l)	875 905 932 958	833 832 818 819	4.8 % 8.06 % 12.23 % 14.50 %
Turbidity(NTU)	6.9 31.7 34.8 23.5	3.2 10.3 10.6 7.5	53.62% 67.50% 69.54% 68.08%
pH	8.6 8.5 8.7 8.0	8.0 8.2 8.3 7.7	-
Hardness(mg/l as $CaCO_3$)	168 168 168 168	160 156 160 160	4.76% 7.14% 4.76% 4.76%

Table 6b. Average Percentage Removal Efficiency of Experimental Setup-IV

Characteristics	%Removal Efficiency				Average % Removal Efficiency
COD (mg/l)	100%	100%	93.29 %	90.47 %	95.94%
TSS (mg/l)	80.76 %	90.5%	93.2%	93.2%	89.72%
Turbidity (NTU)	53.62 %	67.50 %	69.54 %	68.08 %	64.69%

Figure 5 shows comparison of the removal efficiency of parameters from all four experimental setups.

Conclusions

The performance of Multicompartment Sand Filter (MCSF) was tested for

1. Different sizes of the drawers
2. Different combinations of the filter media (sand and earthen clay pot pieces).
3. Number of drawers.

The results obtained after experimentally examining MCSF for above mention points are as follows.

- Different sizes of drawers:- By using two different sizes of drawers only the rate of filtration reduces from 6 l/hr to 2.5 l/hr. The efficiency of MCSF to reduce COD remains same which is greater than 90%.
- Different combinations of filter media: - The combination of gravel in the topmost first tray with earthen clay pot pieces in the second tray from the top and activated charcoal is more efficient than the combination of gravel, sand and activated charcoal in case of TDS and COD removal.

- Number of drawers: - Removal efficiency of parameters remains unaffected for decreasing number of drawers.

Overall efficiency of all the four set-ups shows greater than 90 % removal in COD. Total suspended Solids and Turbidity was also reduced greater than 70% and 60% respectively in all the set-ups. Remaining parameters that are pH, TDS and Hardness do not show any significant change.

In synthetic grey water preparation coconut oil was used. After treatment, no traces of any oil was observed. The colour of treated grey water also appeared lighter as compared to raw sample. The synthetic grey water due to its components of composition, had odour which was totally removed after this treatment. It is observed that the treated sample when kept for few days, no significant odour was found.

It is observed that, MCSF is easy to use and easy to maintain, and due to its iron frame work which is adjustable as required according to the dimension of drawers, it is flexible, requires less area, effective and most importantly economical. The land footprint of MCSF is minimal; it typically takes 1 m^2 drawers and can be placed on the roof top or in the backyard in a small space, making it ideal for densely populated areas (Pazare etal.2018) where land scarcity is a major problem due to growth in population and other developments. Another benefit of MCSF is that it is easy to use and maintain, making it suitable for a wide variety of users.

Further work will be carried out using different filter media, to check the removal efficiency from every drawer and regeneration of media.

References

Abeer Albalawneh, Tsun-Kuo Chang (2015), "Review of the grey water and proposed grey water recycling scheme for agricultural irrigation reuses", *International Journal of Research- Granthaalayah, 3*(12),16-35.

Almoayied Assayed, Jonathan Chenoweth &Steven Pedley (2014), "Drawer Compacted Sand Filter: A new and innovative design for on-site wastewater treatment", *Environmental Technology, 35* (17-20), 2435-2446.

Amal B Mohan Aparna Sasi Archana R Hasweefa Anar Shahima M Mithun B. (2016), "Drawer Compacted Sand Filtration Technique", *International Journal of Scientific & Engineering Research, 7*(4),53-57.

Almoayied Assayed, Jonathan Chenoweth &Steven Pedley (2015)," Assessing the efficiency of an innovative method for onsite grey water treatment: Drawer compacted sand filter - A case study in Jordan," *Ecological Engineering,* 81: 525-533.

Bessy John, Bindu. G, (2017), "Grey water Treatment by Drawer Compacted Sand Filter with Silver Coated Sand", *International Journal of Science Technology & Engineering,* 3, (10), 496-500.

Grey Water Reuse in Rural School-Guidance Manual, *National Environmental Engineering Research Institute,* January 2007.

Jefferson B., Palmer A., Jeffrey P., Stuetz R. and Judd S. (2004). Grey water characterisation and its impact on the selection and operation of technologies for urban reuse. *Journal of Water Science and Technology,* 50(2),157–164.

John N., Abhijith G, Ciji B, Haripriya M, Jivic J Panackal, Sijitha Sidhan (2017), "Modified Drawer Compacted Sand Filter", *International Research Journal of Engineering and Technology:* 04(03), 652-656.

Morel A. and Diener S. (2006), *"Grey water management in low and middle income countries - Review of different treatment systems for households or neighborhoods",* Swiss Federal Institute of Aquatic Science and Technology (Eawag), Dübendorf, Switzerland.

Pazare P. and Waghmare C. (2018), "A Laboratory Scale Analysis of Grey water Using Drawer Compacted Sand Filter", *Journal of Research in Engineering and Applied Sciences, 3*(03), 98-101.

Parameshwara Murthy P. M., Dr. B. M. Sadashiva Murthy, Kavya S, (2016), "Grey water Treatment & Reuse: A Technological Review", *Global Journal for Research Analysis,* 5 (3), 408-410.

Sandhya Pushkar Singh, Nusrat Ali, Sabih Ahmad, Dr. J.K. Singh, (2015), "A Study on Grey water Treatment Processes: A Review", *International Journal for Scientific Research and Development,* 3(08), 413-416

Metcalf and Eddy, George Tchobanoglous (2016), "Waste water Engineering Treatment and Reuse," McGraw-Hill Education.

http://www.un.org/waterforlifedecade/scarcity.shtml, United Nations Department of Economic and Social Affairs (UNDESA), 2014.