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Chemical-Free Greywater Treatment Using Aeration, Sedimentation, Followed by Granular Activated Carbon Filter (GAC) -A Case Study of Baghdad city household

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ABSTRACT

Greywater is a possible water source that can be improved for meeting the quality required for irrigation. Treatment of greywater can range from uncomplicated coarse filtration to advanced biological treatment. This article presents a simple design of a small scale greywater treatment plant, which is a series of physical and natural processes including screening, aeration, sedimentation, and filtration using granular activated carbon filter and differentiates its performance with sand filter. The performance of these units with the dual filter media of (activated carbon with sand) in treatment of greywater from Iraqi house in Baghdad city during 2019 and that collected from several points including washbasins, kitchen sink, bathrooms, and laundry, was recorded in terms of removal efficiency of particular pollutants like Turbidity 94%, chemical oxygen demand (COD) 93%, and oil 91%. Dual filter was the most effective filter for decreasing these pollutants, while sand indicates the lowest removal efficiency. In general, granular activated carbon media seemed to be the most proper medium to improve greywater quality for reaching the quality of irrigation within the terms of organic matter decrease. Accordingly, this technology may be reliable for greywater treatment in a residential area.

Keywords: Greywater, Wastewater treatment, Filtration, Granular Activated Carbon, Chemical oxygen demand.

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معالجة المياه الرمادية بدون اضافات كيميائية بواسطة التهوية والترسيب واستخدام مرشح الكربون المنشط الحبيبي – دراسة حالة الاستهلاك المنزلي في مدينة بغداد

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الخلاصة

المياه الرمادية هي مصدر مائي محتمل يمكن أن يتحسن لتلبية الجودة المطلوبة لأغراض الري. يمكن أن تتراوح معالجة المياه الرمادية من الترشيح الفيزياوي غير المعقد إلى المعالجة البيولوجية المتقدمة. تقدم هذه الدراسة التصميم المناسب لمحطة معالجة المياه الرمادية على نطاق تجريبي، وهي عبارة عن سلسلة من العمليات الطبيعية والفيزيائية والتي تتضمن الغربلة، والتهوية والترسيب والترشيح باستخدام حبيبات الكربون المنشط ومقارنة أدائه مع المرشح الرملي الاعتيادي. تم تسجيل أداء هذه الوحدات من خلال وسائط الترشيح المزدوجة (الكربون المنشط مع الرمل) في معالجة المياه الرمادية حسب الاستهلاك المنزلي لمدينة بغداد خلال عام 2019 والتي تم جمعها من عدة نقاط تشمل: مغاسل اليدين وتصريف المطبخ والحمامات، وغسالة الملابس، من حيث كفاءة الإزالة من ملوثات معينة مثل العكرة 94٪ والمتطلب الكيميائي للأكسجين 93٪ والدهون 91٪. كان الفلتر المزدوج هو المرشح الأكثر فعالية في تقليل هذه الملوثات، بينما وصل الرمل إلى أدنى كفاءة إزالة. بشكل عام، يبدو أن وسائط حبيبات الكربون المنشط هي أنسب الوسائط لتحسين جودة المياه الرمادية للوصول إلى جودة الري ضمن شروط انخفاض المواد العضوية. وفقا لذلك، قد تكون هذه التكنولوجيا موثوقة لمعالجة المياه الرمادية في منطقة سكنية.

الكلمات الرئيسية: المياه الرمادية، معالجة مياه الصرف الصحي، الترشيح، حبيبات الكربون المنشط، المتطلب الكيميائي للأكسجين.

1. INTRODUCTION

Euphrates and Tigris Rivers are the primary source of water in Iraq, which produces a high agricultural used water percentage for thousands of years. In past years, Iraq suffered from water scarcity sources because of global climate variations and the inequitable water politics of the adjacent countries **(Al-haddad** and **Al-Safi, 2015)**. In this regard, Baghdad city faced numerous issues concerning deteriorations of the freshwater environment because of several reasons, principally was discharging of wastewater without sufficient treatment **(KIhudair** and **Jasim, 2017)**. Alternative water sources became more critical in areas suffering from water scarcity. The high shortage of water sources in the developing countries urged the governments to look for alternative sources. One of the most beneficial sources of water is represented by the greywater, because of the less pollution in comparison by sewage **(Al-Gheethi, et al., 2015)**. The division of blackwater from greywater is the primary step for proper management proposed to facilitate the treatment process. In addition to this, there are several advantages for the separation operation of the blackwater from greywater that includes the amount of energy used about 11.8–37.5% of that energy corresponding to the sewage treatment processes **(Al-Gheethi, et al., 2015)**, being the most significant wastewater stream in the household, also presenting low concentrations of nutrients.

Moreover, a lower amount of microbiological pathogens than latrine wastewater (blackwater), greywater represents a non-conventional high-quality source of water **(Pidou, et al., 2007)**. Nevertheless, to consider the income of the nations didn't show a noticeable trend between high and low-income since the greywater generation in high-income nations is higher, however, in low-income countries, some pollutants concentration is higher **(Ghaitidak** and **Yadav, 2013)**. Greywater production in the Middle East differs from 16 to 161 liters per capita per day **(Prathapar, et al., 2006)**, **(Al-Hamaiedeh** and **Bino, 2012)**, which explains that geographic location isn't the exclusive reason for the trends variety. Greywater is a possible water source, which may be upgraded to meet the irrigation quality required **(Dalahmeh, et al., 2012)**. In this regard, aeration process may be helpful to do this since it is defined as the method of bringing air and water into approaching contact with each other **(Ghernaout, 2014)** to reduce unwanted water pollutants, by oxidizing several natural organic matters (NOM), **(Ghernaout, et al., 2014)** and enhancing the treatability of water. Aeration has been employed efficiently in water treatment to decrease the level of taste and odor-producing constituents like hydrogen sulfide and some synthetic, to eliminate carbon dioxide. Nevertheless, employing aeration just for the target of controlling chemical oxygen demand is a good idea in the greywater treatment **(Ghernaout** and **Ghernaout, 2012)**. A system of laboratory-scale greywater treatment was designed by **(Shegokar, et al., 2015)**. It consisted of five units of physical operations as raw greywater unit, sedimentation, first filtration unit of gravel and sand, second dual filtration unit, and collecting unit for treated greywater. So the results explained that the nylon rope filter recorded better execution in the filtration unit as compared to dual filters, plus individually used the activated carbon filter. Dissolved pollutants (organic and inorganic) of water can be removed through an effective adsorption technique. Activated carbon (AC) is very familiar with all types of adsorbents due to high adsorption capacity **(Gwenzi, et al., 2017)**. The adsorption frequency of activated charcoal relates to its great surface area, high pores distribution, and rapid grade of external reactivity. A system including biofilm up-flow expanded bed (UEB) reactor of a granular activated carbon (GAC) and a slowdown flow packed sand filter was installed by the professors **(Al-Mughalles, et al., 2012)** for greywater treatment collected from the mosque (ablution water). The research results indicate that the system is efficient, and it has shown an adequate level of performance in the organic chemical pollutant (chemical oxygen demand) and the physical contaminate (total suspended solids) treatment. The concentrations of the pollutant in the effluent of the treated water were suitable for Yemeni irrigation specifications. The objective of the present research was to analyze and compare the reduction of chemical oxygen demand (COD), oil, and turbidity, from real greywater for two different filters media, namely granular activated carbon and sand. Assess proper filters for small-scale greywater treatment was the general aim of the research, to provide treated water to use it in the crop irrigation.

2. Materials and Methods

2.1 Study Area Description

To take into account various patterns of water use at the fixtures, three local households characterized by a different number of users mostly heterogeneous for gender, age, customs, and occupation, were selected for collecting the greywater, as a case study in Baghdad city in the middle of Iraq. The real greywater used came from laundry, bathroom, kitchen sink, and washbasin.

2.2 Grey Water Sampling and Analysis

Greywater average quantity was estimated in three different houses sites during summer. Each one has various family characteristics. The average greywater generated was 181 L/c.d, which accounts for about 40.2% of the proposed quantity of water supplied by the municipality for urban areas 450 L/c.d. The greywater percentage, according to each fixture, as shown in **Fig. 1** as a Pie chart. Collected samples were transferred to the "Ministry of Science and Technology" (Environmental and Water Research and Technology Directorate), to analyze the selected samples for significant physical and chemical characteristics. **Table 1.** explains the characteristics of greywater during the study period.

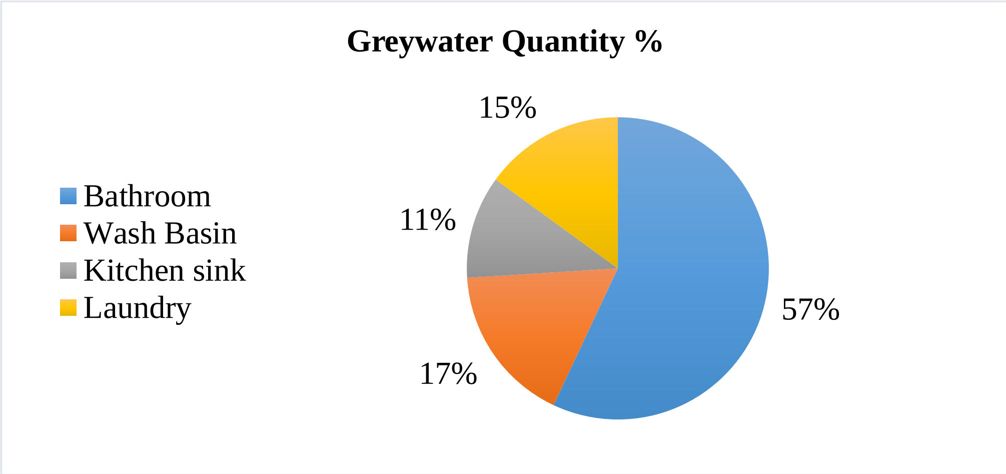

Figure 1. The percent of greywater produced in the study area during summer.

Table 1. The greywater characteristic during the study period.

No.	Parameter	Rang
1	pH	6.4 – 7.1
2	Turbidity (NTU)	131 – 400
3	TDS (mg/L)	400 – 605
4	EC (μs/cm)	667 – 1010
5	COD (mg/L)	725 – 876
6	Oil (mg/L)	92 – 123
7	HCO_3 (mg/L)	130 – 180
8	Ca^{+2} (mg/L)	150 – 230
9	Mg^{+2} (mg/L)	35 – 60
10	Na^{+} (mg/L)	65 – 100
11	Cl^{-} (mg/L)	100 – 130

2.3 Granular Activated Carbon (GAC) Analysis

The most usually applied method for greywater treatment is sand filtration. Lack of well-graded sand in some areas, clogging problems, and expensive transportation costs because of the high bulk density are restrictions in using sand filters **(Spychala** and **Blazejewski, 2013)**. Therefore, alternative materials like granular activated carbon with low bulk density, proper physicochemical characteristics allowing accessible for handling and transportation may be an attractive alternative. However, it must be examined for decreasing biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), nutrients, microbial pollutants, and surfactants also compared with sand before using in large-scale **(Roy, et al., 1998)**. An insufficient number of researches on the reduction of these parameters in filters using carbon as bio carriers were reported. Furthermore, none of them concentrated on producing water for irrigation. Carbon appears to have a high ability to reduce COD and BOD_5, making it promising for the treatment of greywater **(AHSAN, et al., 2001)**. But, the potential of this media for the organic matter reduction from greywater to produce irrigation water needs more study. **(Dalahmeh, et al., 2012)** estimated the performance of polyurethane foam, activated charcoal, bark, and sand filters in reducing nitrogen, biochemical oxygen demand (BOD_5), microbial indicators, and phosphorus from greywater. For 113 days, filters with 20 cm diameter and 0.6 m high were fed in the column experiments by artificial greywater. Activated charcoal and bark efficiently decreased the concentrations of organics (BOD), total phosphorus (TP), and surfactants, while foam and sand were less effective. Foam, activated charcoal, bark, and sand decreased influent BOD_5 by 37, 97, 98, and 75%. In this regard, activated charcoal and bark filters seemed to be the most proper filters to improve greywater quality for reaching quality for irrigation in terms of organic matter decrease.

Figure 2. Activated Carbon.

Sieve analysis was achieved on the Granular activated carbon according to **(ASTM, 1970)**. **Fig. 3** shows the graphical representation of the sieve analysis results, while **Table 2.** explains its characteristics.

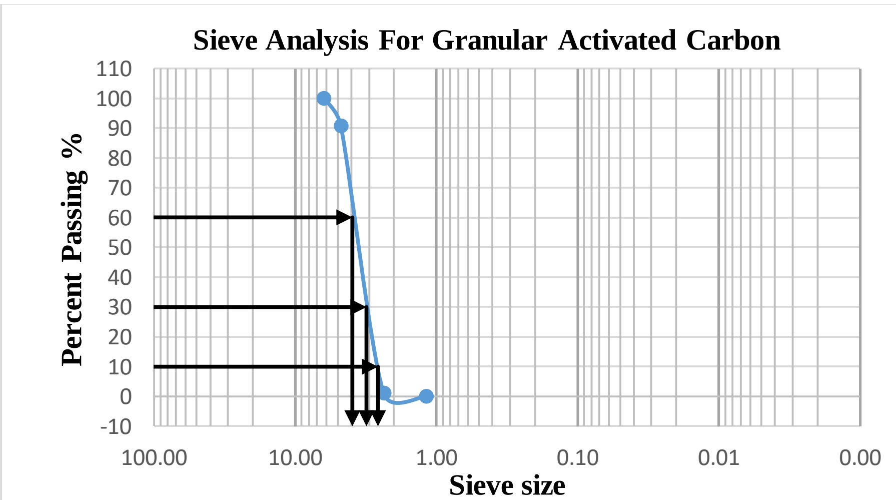

Figure 3. Sieve Analysis for Granular Activated Carbon media.

Table 2. Analysis of Granular Activated Carbon.

Property	Value
D_{60}	3.93
D_{10} Effective size	2.60
(Cu) Uniformity coefficient	1.51
(Cc) Coefficient of curvature	0.96
(Ct) Sorting coefficient	1.20

2.4 Experimental work

The treatment series is explained in the schematic diagram **Fig. 4**. The treatment systems were screening the greywater in 1mm; then, it was collected in a trapezoidal plastic tank with a volume of about 100 liters as an aeration tank, as shown in **Fig. 5 a**. Two diffusers with a discharge of 210 L/hr, as shown in **Fig. 5 b,** of four ventilation plates, distributed in four parts at the bottom of the tank to provide adequate oxygen and remove colors, taste, and odors from greywater. In addition to this, it helps in decreasing the amount of oil and the chemical oxygen demand. During this process, air and water are in intimate contact. The greywater was transformed from the aeration tank to a sedimentation tank. Its detention time is between 1 and 2 hr., settling the greywater in the settling tank in the absence of any chemicals, so the largest amount of the suspended impurities presents in greywater tend to settle down by gravity after that greywater was pumped through a submersible pump of 1400 L/hr discharge capacity and 2.8 m head as shown in **Fig. 5 c** to the filter containers passing it through the flow meters, which record from zero to 250 mL/min, as shown in **Fig. 6 b**.

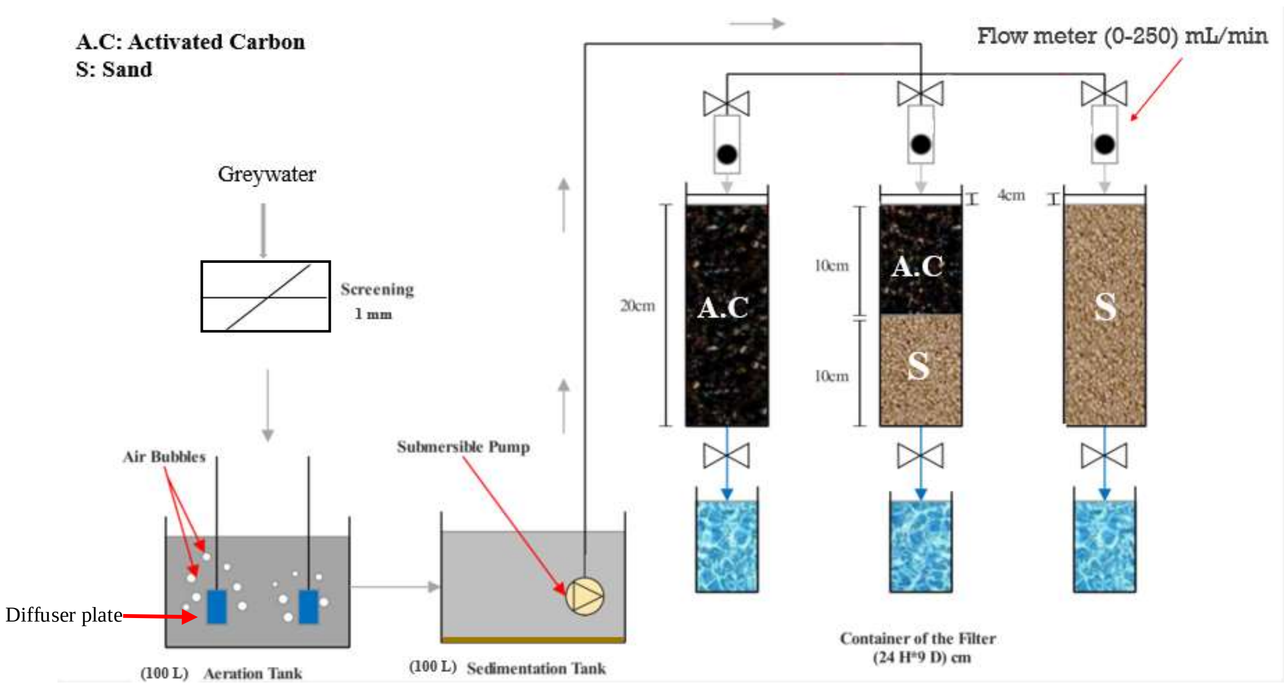

Figure 4. Schematic diagram of the set (Flow diagram).

The filter containers dimensions are 24 cm in height and 9 cm in diameter. The mono-media filter in container No. 1, which is 20 cm granular activated carbon and in container No. 2, the dual media including 10 cm granular activated carbon and 10 cm sand. While container No. 3 is the sand filter, all filters with 4 cm head, as shown in **Fig. 6 a.** In this research, three runs were conducted of 1, 2, and 3 hours in the aeration tank, and four flow rates were chosen for the influent discharge to the filter, which are 25, 50, 75, and 100 mL/min in each run. The treatability investigations were carried out for greywater treatment using low-cost technological options also to minimize the greywater pollutant load.

(a)

(b)

(c)

Figure 5. (a) Aeration tank. (b) Air diffuser 210 L/hr. (c) Pump 1400 L/hr.

(a) (b)

Figure 6. (a) Filter system. (b) Flowmeter**.**

3. Result and Discussion

High concentrations of (Turbidity, COD, and Oil) were recorded in samples from the kitchen sink, bathroom, laundry, and washbasins. This can explain by the activities of the family at home, like detergent, washing dishes, shampoo, soap, combing and brushing, tooth brushing, and hair dyes, mainly during the morning, as shown in **Table 3**. Higher concentrations of chemical oxygen demand were coming from kitchen sinks samples, possibly due to the presence of the detergent in it. The same thing has been observed in oil that may occur because of the amount and variety of foods. At the same time, the high amount of turbidity may be caused by the laundry and handwashing. The highest removal efficiency was recorded in the dual media filter, and the duration of aeration was two hours with the flow rate influent to the filter of 50 mL/min, which is 94%, 93% and 91% for turbidity, chemical oxygen demand, and oil respectively, as shown in **Figures (10,11 and 12)**. This chemical oxygen demand removal efficiency is close to the removal efficiency of the research of the professors **(Dalahmeh, et al., 2012)**, where the removal efficiency about (94±2 %). At the same time, the turbidity removal efficiency is a little greater than that removal efficiency in the research of the professors **(Shegokar, et al., 2015)** where it is about (82%). In this regard **(Jawaduddin, et al., 2019)** analyzed that the combined filters (Activated Carbon and river sand) were very operational in treating greywater. Compared with BOD, synthetic greywater has a higher COD value. In addition to that, during the treatment, the average removal efficiency of turbidity was analyzed to be 91.3%.

Table 3. Treated greywater characteristics.

No.	Parameter	Treated greywater Rang	Iraqi Effluent Limitations 2012
1	pH	6.6 - 7	6.4 - 8
2	Turbidity(NTU)	51 - 180	
3	TDS (mg/L)	445 - 480	2500
4	EC (µs/cm)	850 - 933	
5	COD (mg/L)	110 - 200	100
6	Oil (mg/L)	10 - 25	-
7	HCO_3 (mg/L)	115 - 135	
8	Ca^{+2} (mg/L)	110 - 135	450
9	Mg^{+2} (mg/L)	24 - 43	80
10	Na^{+} (mg/L)	60 - 70	250
11	Cl^{-} (mg/L)	78 - 90	
12	CO_3 (mg/L)	Nil	-

3.1 Effect of filter media on removal efficiency

Probably sand is the most popularly used filter media for the treatment of greywater today. Nevertheless, sand has a relatively small specific surface area and high bulk density. In this research, the purification ability of sand was compared with granular activated carbon, since this media has a higher specific surface area and lower bulk densities than sand where the sand filter shows the lowest removal efficiency among the three filters.

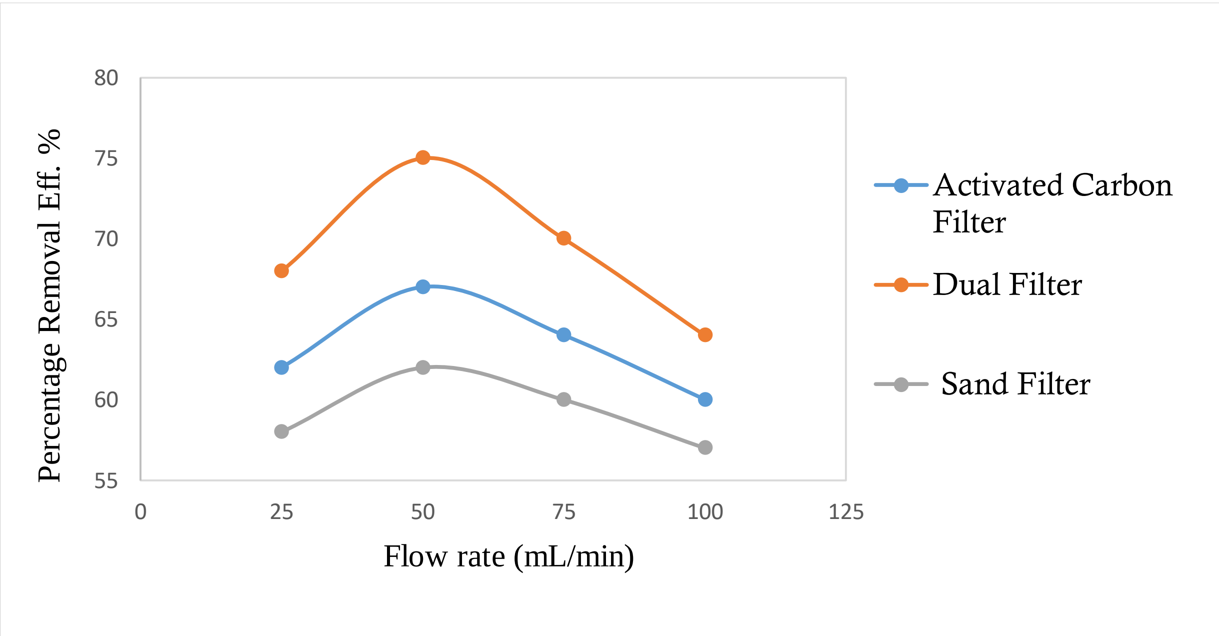

Figure 7. Chemical oxygen demand Removal Efficiency (1-hr. Aeration time).

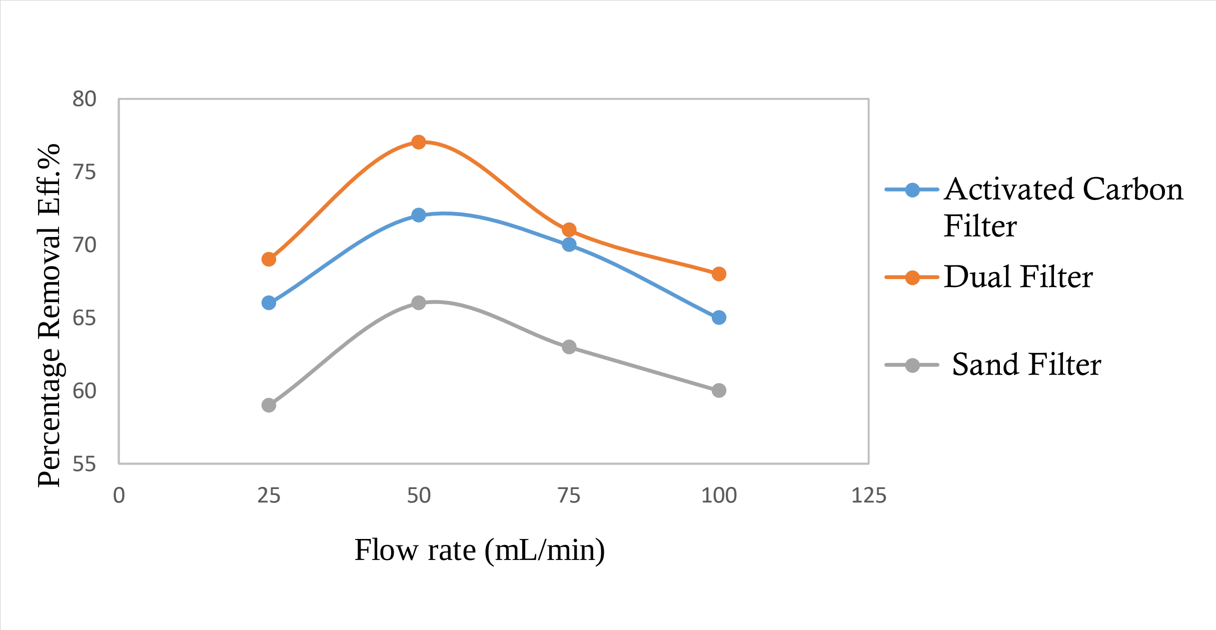

Figure 8. Oil Removal Efficiency (1-hr. Aeration time).

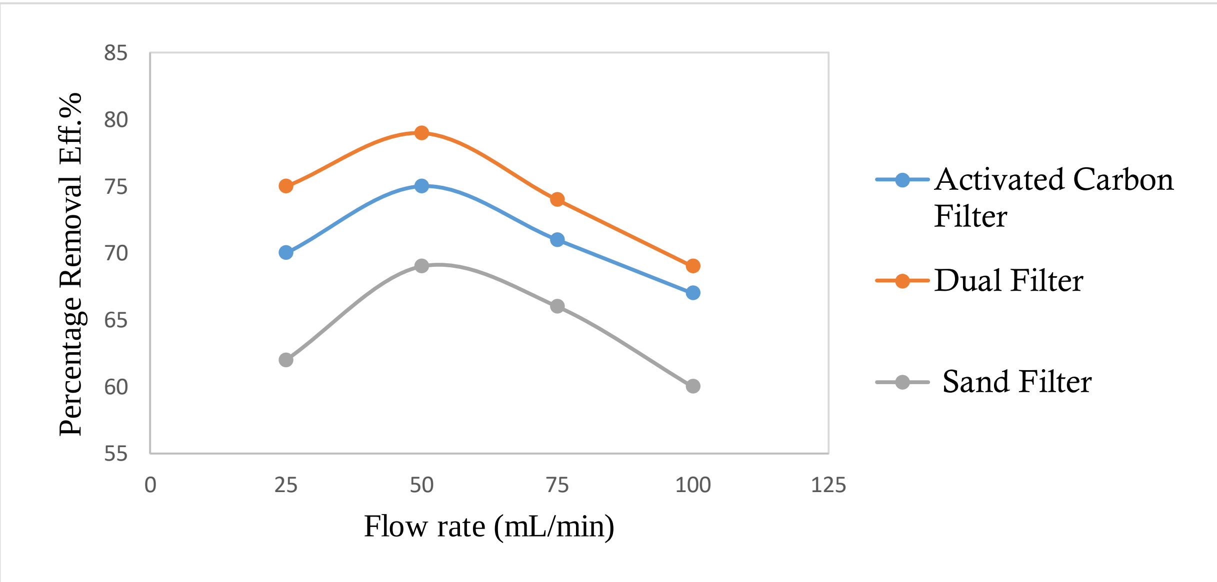

Figure 9. Turbidity Removal Efficiency (1-hr. Aeration time).

3.2 Effect of Aeration process time on removal efficiency

During one-hour aeration process, the results were less efficient removal from the two-hour operation, for the specific contaminants, where the highest removal efficiency values were found 79, 75 and 77% for turbidity, chemical oxygen demand, and oil, respectively with a flow rate of 50 mL/min as shown in **Figures (7, 8 and 9)**. Experimental work explained that the removal efficiency of turbidity, chemical oxygen demand, and oil increases when aeration time exceeds one hour. Due to the boost in the quantity of oxygen that is pumped inside the greywater, thus decreasing the amount of the chemical oxygen demand, while the oil and grease become more and more, and float on the tank surface, then it is scraped manually periodically.

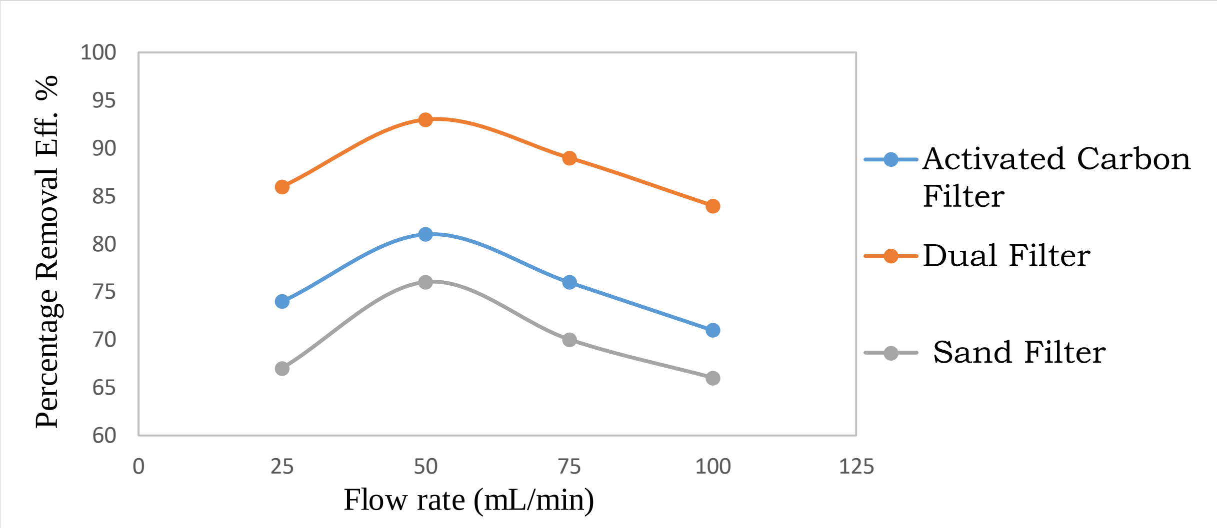

Figure 10. Chemical oxygen demand Removal Efficiency (2-hr. Aeration time).

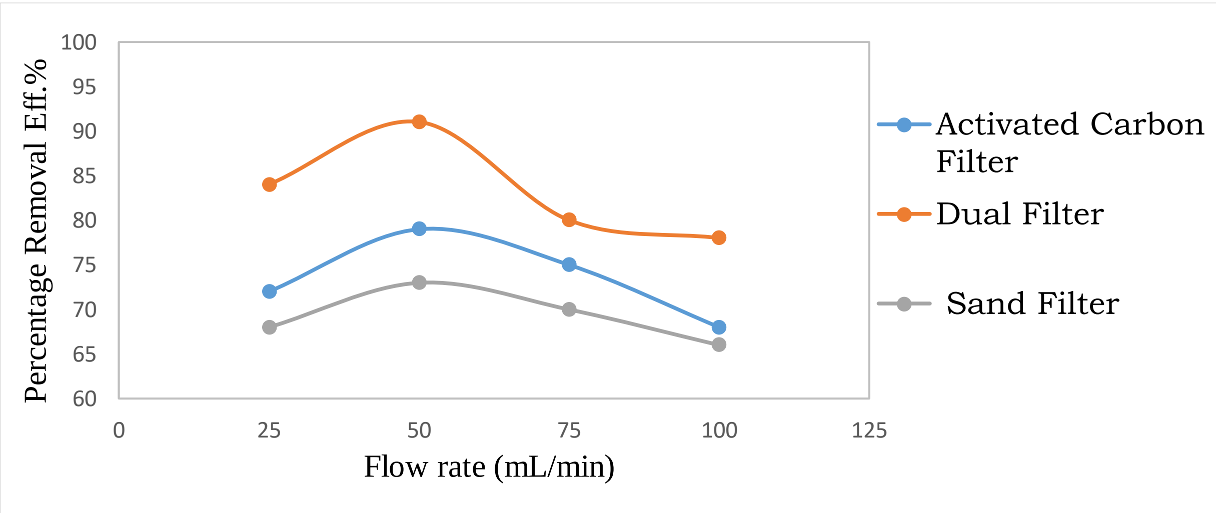

Figure 11. Oil Removal Efficiency (2-hr. Aeration time).

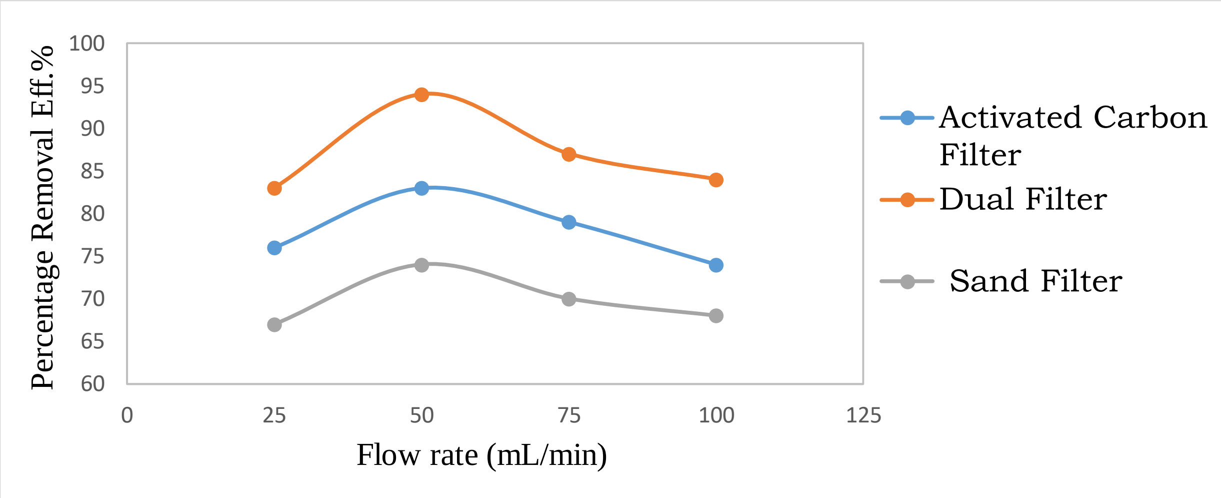

Figure 12. Turbidity Removal Efficiency (2-hr. Aeration time).

4. CONCLUSIONS

This research investigates the real greywater characteristics and treatment systems. Through experimental work by using a small scale, conventional treatment systems. Based on the prior results, important conclusions can be summarized in some points:

1. Greywater's average production rate was found to be 181 L/c.d in the study area.
2. Artificial aeration significantly increasing dissolved oxygen concentration, and that enhances the reduction in chemical oxygen demand.
3. More research is required to understand best the influence of implementing the aeration process in greywater treatment.
4. The three filtration systems tested (granular activated carbon, dual, and sand) were truly simplified, and operated well by gravity.
5. Granular activated carbon seems to be proper media using in filter systems to treat greywater to be fit for irrigation water quality, concerning turbidity, chemical oxygen demand, and oil. Accordingly, this technology may be reliable for greywater treatment in a residential area.

REFERENCES

- Al-haddad, A. H., and Al-Safi, A. I. B., 2015. Scheduling of Irrigation and Leaching Requirements. *Journal of Engineering*, Volume 21 (3), pp. 73-92.

- Al-Hamaiedeh, H., and Bino, M., 2010. Effect of treated greywater reuse in irrigation on soil and plants. *Desalination*, Volume 256(1-3), pp. 115-119.

- AHSAN, S. et al., 2001. Use of some natural and waste materials for wastewater treatment. *Water Research*, Volume 35(15), pp. 3738-3742.

- Al-Gheethi, A. A. et al., 2015. Removal of heavy metals and antibiotics from treated sewage effluent by bacteria. *Clean Technologies and Environmental Policy,* Volume 17(8), pp. 2101-2123.

- Al-Mughalles, M. H. et al., 2012. Greywater treatment using GAC biofilm reactor and sand filter system. *Australian Journal of Basic and Applied Sciences,* Volume 6 (3), pp. 283-292.

- ASTM, 1970. *Special Procedures for testing soil and rock for engineering purposes.* Fifth ed. Philadelphia: American Society for Testing and Materials.1916 Race Street, Philadelphia, Pa. 19103.

- Dalahmeh, S. S. et al., 2012. Efficiency of bark, activated charcoal, foam and sand filters in reducing pollutants from greywater. *Water, Air, and Soil Pollution,* Volume 223 (7), p. 3657–3671.

- Ghaitidak, D. M. and Yadav, K. D., 2013. Characteristics and treatment of greywater—a review. *Environmental Science and Pollution Research,* Volume 20(5), pp. 2795-2809.

- Ghernaout, D., 2014. The hydrophilic/hydrophobic ratio vs. dissolved organics removal by coagulation–A review. *Journal of King Saud University-Science,* Volume 26 (3), pp. 169-180.

- Ghernaout, D., and Ghernaout, B., 2012. On the concept of the future drinking water treatment plant: algae harvesting from the algal biomass for biodiesel production—a review. *Desalination and Water Treatment,* Volume 49(1-3), pp. 1-18.

- Ghernaout, D. et al., 2014. Coagulation, and chlorination of NOM and algae in water. *International Journal of Environmental Monitoring and Analysis,* Volume 2 (3), pp. 23-34.

- Gwenzi, W., Chaukura, N., Noubactep, C., and Mukome, F. N., 2017. Biochar-based water treatment systems as a potential low-cost and sustainable technology for clean water provision. *Journal of environmental management,* Volume 197, pp. 732-749.

- Jawaduddin, M. et al., 2019. Synthetic Grey Water Treatment Through $FeCl_3$-Activated Carbon Obtained from Cotton Stalks and River Sand. *Civil Engineering Journal,* Volume 5 (2), pp. 340-348.

- Khudair, B. H., and Jasim, S. A., 2017. Performance Evaluation of Sequencing Batch Reactor and Conventional Wastewater Treatment Plant based on Reliability assessment. *Journal of Engineering,* Volume 23 (11), pp. 97-112.

- Pidou, M. et al., 2007. Greywater recycling: treatment options and applications. *Engineering Sustainability,* Volume 160(3), pp. 119-131.

- Prathapar, S. A., Ahmed, M., Al Adawi, S., and Al Sidiari, S., 2006. Design, construction and evaluation of an ablution water treatment unit in Oman: a case study.. *International journal of environmental studies,* Volume 63(3), pp. 283-292.

- Roy, C., Auger, R., and Chenier, R., 1998. Use of non woven textile in intermittent filters. *Water science and technology,* Volume 38(3), pp. 159-166.

- Shegokar, V. V., Ramteke, D. S., and Meshram, P. U., 2015. DESIGN AND TREATABILITY STUDIES OF LOW COST BIO-FILTER IN GREY WATER TREATMENT WITH RESPECT TO RECYCLE AND REUSE IN RURAL AREAS. *International Journal of Current Microbiology and Applied Sciences,* Volume 4 (8), pp. 113-124.

- Shegokar, V. V., Ramteke, D. S., and Meshram, P. U., 2015. Design and Treatability Studies of Low-Cost Grey Water Treatment with Respect to Recycle and Reuse in Rural Areas. *Int. J. Curr. Microbiol. App. Sci,* Volume 4 (8), pp. 113-124.

- Spychala, M., and Blazejewski, R., 2003. Sand filter clogging by septic tank effluent.. *Water science and technology,* Volume 48(11-12), pp. 153-159.