Journal of Engineering and Sustainable Development
Vol. 28, No. 06, November 2024
https://jeasd.uomustansiriyah.edu.iq/index.php/jeasd
ISSN 2520-0917
Research Article
https://doi.org/10.31272/jeasd.28.6.11

Performance of Agricultural Wastes as A Biofilter Media for Low-Cost Greywater Treatment Technology

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Article Info

Received 17/12/2023
Revised 17/10/2024
Accepted 17/10/2024

Abstract

Iraq currently faces an absence of water, worsened by population growth. As a result, if new water sources are not supplied, the country's yearly per capita water supply will decrease. This study developed a simple, promising, and economical method for on-site greywater treatment, employing agricultural waste as a biofilter medium and irrigation water in rural Iraqi areas. Experiments were carried out in this study to evaluate the multimedia filter device's efficacy in treating greywater. Three bioreactor columns were filled to the necessary height with various substrates—wood chipsBTF1, rice huskBTF2, and date palm fiberBTF3 at different operation conditions. The pollutant removal efficiency (Chemical Oxygen Demand, Total suspended solids, nitrate, and Phosphorous) for BTF1 was 61.6, 70.3, 45 and 42.45, for BTF2, it was 65.7, 43, 50.21%, and 55%. And for BTF3, it was 63.3, 75.6, 55, and 52.52, respectively. Rice husk is the most effective medium for eliminating pollutants, and using agricultural wastes as biofilter media could be a promising option for greywater treatment, especially in rural areas that lack sanitation services and produce a high amount of this waste annually.

Keywords: Agricultural wastes; Date Palm Fiber; Media; Rice husk; Wood Chips

1. Introduction

Wastewater from the kitchen, laundry, and bathroom is a common term for greywater. Iraq currently faces an absence of water, worsened by population growth. As a result, if new water sources are not supplied, the country's yearly per capita water supply will decrease. This study developed a simple, promising, and economical method for on-site greywater treatment, employing agricultural waste as a biofilter medium and using it as irrigation water in rural Iraqi areas. This would lessen the quantity of organic waste dumped into the environment. Experiments were carried out in this study to evaluate the multimedia filter device's efficacy in treating greywater. Three bioreactor columns (BTF1, BTF2, and BTF3) were filled to the necessary height with various substrates—wood chips, rice husk, and date palm fiber, respectively, as well as layers of sand and gravel. Each biofilter was tested with varying hydraulic retention times (12, 24, and 48 hours) and agricultural waste media substrate heights (15 and 20 cm). The organic and nutrient pollutant removal efficiency (Chemical Oxygen Demand COD, Total suspended solid TSS,nitrat NO_3, and Phosphorous PO_4) for BTF1was 61.6, 70.3, 45 and 42.45 respectively, for BTF2 it was 65.7, 43, 50.21% and 55% respectively. And for BTF3, it was 63.3, 75.6, 55, and 52.52 respectively [1].

Rice husk is the most effective medium for eliminating pollutants from greywater. The use of agricultural wastes (rice husk, date palm fiber, wood chips) as biofilter media in greywater treatment could be a promising option for the greywater treatment, especially in rural areas that suffer from a lack of sanitation services and have a high amount of these wastes produced annually this option may offer economical and green engineering solution. This study shows the possibility of decreasing the total potable water demand by reusing greywater for restricted irrigation. All water drains from a house are greywater, except toilet waste [2]-[4]. As industrialization and development increase in developing countries, there are more alternatives for greywater reuse [5]-[6].

Due to the wide range of household water consumption, greywater quality varies greatly. It includes pollutants such as nutrients, bacteria, and organic substances. When contrasted with raw sewage or black water, the pollutant amounts in greywater are far lower. A significant amount of organic waste is generated in kitchens, raising concerns about potential pathogenic contamination [7], [8]. Greywater yields 90 to 120 l/p/d on average [9].

According to the literature, approximately 27% of greywater comes from the dishwasher and kitchen sink. Roughly 47% of the space is accounted for by the washbasin, shower, and bathroom, and approximately 26% is occupied by the laundry and dishwasher [10], [11]. Due to the residents' lifestyle decisions, greywater is generated [3], [10]. The population's lives, social and cultural relationships, water availability, and consumption level all impact the area's properties, which is why they are so changeable[12]. Heavy metals, inorganic ions, suspended particles, different organic compounds, and E. coli are all present in greywater [12], [13].

Contrary to what is commonly believed, these contaminants are more prevalent in greywater than wastewater, according to several studies [14]. The many characteristics of greywater vary depending on the season, the time of day, and the quantity and quality of the water. Gray water reuse and reclamation should adhere to four standards: financial feasibility, environmental toleration, sanitary security, and aesthetic attractiveness. The different reuse activities have varied demands for water quality, so other simple and complex treatments are needed for them [2],[15]. Combining physical filtration with an aerobic biological process is the most practical and efficient technique for treating greywater. For urban residential structures, the biological trickling filter of the multimedia biofilter is a great choice[16].

Due to our particular circumstances, Iraq no longer reuses its water resources. Because Iraq is among the nations with cheap, plentiful sources of clean water to meet our everyday needs, a tiny field or flowerbed can be found in front of most Iraqi homes, and to keep them lush, thousands of gallons of water are used daily. As a pastime or to improve food safety, a significant portion of Iraqi citizens engage in urbanized agriculture and food plantation operations. Because Iraqi waterways are becoming more polluted and have lower water levels, costs could rise, and efficient water usage will become more crucial for households, companies, and farms [17], [18].

Biofilters are among the systems used to treat wastewater [19]. Wastewater, such as sewage, flows downwards over a stationary layer of different substances like ceramic, coke, pebbles, slag, gravel, sphagnum peat moss, polyurethane foam, or plastic media. This flow causes a layer of microbial slime, biofilm, to grow and cover the media bed. Aerobic conditions could be maintained in the filter media if it is porous, either through natural air convection or by forcing air to flow through the bed. Splashing and diffusion both play a role in this process. One of the most established and well-studied treatment methods is using trickling filters to treat sewage and other pollutants. The terms trickle filter, trickling biofilter, biofilter, biological filter, and biological trickling filter often refer to a trickling filter. This study aims to assess the effectiveness of biofilters employing agricultural waste media, specifically rice husk, woodchips, and date palm fiber. These materials are abundantly available in various regions of Iraq, particularly in the rural areas, where they are not being utilized economically. Three biofilter reactor systems are employed to assess their efficiency in pollutant removal. This study evaluates the impact of media depth and contact time on the removal efficiency of pollutants, including COD, TSS, NO3, and PO4.

2. Materials and method

2.1 Selection of the study area

The study area was suggested to be the rural areas surrounding Baghdad's capital. These areas are distinguished by their rural nature, lack of a regular sewage network, and easy access to agricultural waste, which can be used to treat gray water and reuse the treated water for home garden irrigation**.**

Greywaters were obtained once a week for three weeks from three households in the research area by composite sampling in the afternoon and morning. Utilizing 15 L buckets, equal greywater volumes of 10 L were collected from the bathroom, kitchen, and washing machines and delivered by buckets.

Greywater from a kitchen sink, laundry machine, washbasin, and bathroom were collected from various households in Baghdad City, Iraq, for this study, as illustrated in Table 1 and Fig. 1.

Table 1. Production of greywater in the research area

Fixture	Quantity (L/c.d)	Percent %
Wash Basin	27	17
Bathroom	90	56
Laundry	24	15
Kitchen sink	20	12
Total	161	100

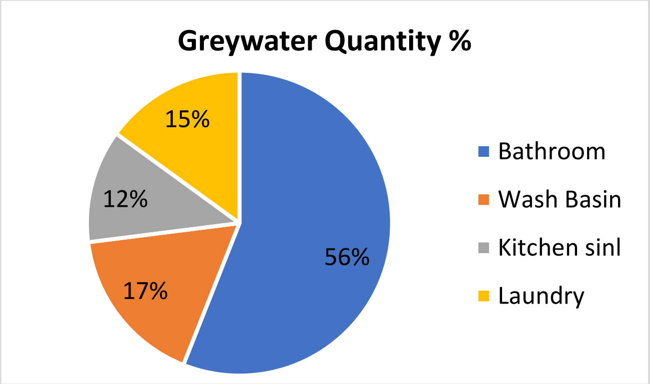


Figure 1. The percent of greywater produced in the study area

2.2 Collection and characterization of greywater

Several greywater sources, such as laundry, washbasins, kitchen sinks, and post-shower water, were identified. The drainage pipes from these sources were organized to direct their flow into separate 5-liter containers after being disconnected from the central wastewater collection stream. The research aimed to characterize the different sources of greywater or the specific locations where greywater is produced, as previously mentioned. The samples were extracted from the collection tanks and subjected to laboratory analysis to determine the concentrations of various parameters. Table 2 presents the characteristics of the gathered greywater sample and compares it to the standards set by Iraq.

Table 2. Statistical analysis of the physicochemical properties of the collected influent greywater sample. greywater

Parameter of Column A	Units	N	Mean (x)	Std	Minimum value	Maximum value	Mean±Std (Before Filtration)	Iraqi Standard 2012
pH	–	15	7.9	0.4	6.56	9.43	7.9 ± 0.4	(6.5-8.5)
Temp.(Ċ)	(Ċ)	10	23.5	0.3	22	25	23.5 ± 0.3	-
Turbidity	NTU	10	210	10.6	188	233.35	210.5 ± 10.6	
EC	µs/cm	15	922.5	232.6	815.6	1028.9	922.5 ± 232.6	
(TDS)	mg/l	15	456.5	117	432.5	480	456.5 ± 117	2500
BOD5	mg/l	15	180	40	166	195	180 ± 40	40
COD	mg/l	15	290	50	201	380	290 ± 50	<100
TSS	mg/l	10	187	50	140	240	187 ± 50	40
PO_4	mg/l	10	1.15	0.8	0.95	1.35	1.15 ± 0.8	25
NH_4-N	mg/l	15	25.65	5.4	21.8	29.5	25.65 ± 5.4	5
Nitrates	mg/l	15	3.5	2.5	2.66	4.5	3.5 ± 2.5	50
K^{+1}(mg/l)	mg/l	15	13.4	0.4	12.8	14.8	13.4± 0.4	100
Na^{+1}(mg/l)	mg/l	15	134.8	4.5	118.9	150.3	134.8 ± 4.5	250
Ca^{+2}(mg/l)	mg/l	15	215.8	5.4	185	246	215.8 ± 5.4	450
Mg^{+2}(mg/l)	mg/l	15	155.8	0.4	177.9	137	155.8 ± 0.4	80
SAR	Meq/l	15	0.8	0.25	0.7	1.1	0.8 ± 0.25	
$CaCO_3$(mg/l)	Mg/l	15	15.8	0.4	12.7	17.8	15.8 ± 0.4	300
So_4^{-2}(mg/l)	Mg/l	15	58.8	10	49.9	66.9	58.8 ± 10	200
Fecal Coliform	CFU/100ml	15		-	-	-	80000	-
Total Coliform	CFU/100ml	15		-		-	95000	-

2.3 Experimental Setup

The pilot-scale of the biofilter was carried out in-house. Fig. 2 depicts the schematic diagram of the BTF experimental system (the system was chosen following a review by Anne Tusiime et al. [20].

The treatment system consisted of three stacked columns named BTF1, BTF2, and BTF3, each with an inner diameter of 15 cm and a total height of 50 cm. Positioning the elevated tank on a platform constructed higher above the reactor column filters made the gravity flow of raw greywater into the tank possible.

To facilitate the process of filling the tank with gray water, the storage tank with a submersible pump (2.8 m head and 1400 L/hr discharge capacity) was positioned below the BTF levels with gray water during the experiment. Pre-treatments involving screening, fats, oil skimming, and sedimentation

Fig. 2. shows the system structure. Pipes with a ¾-inch diameter and gate valves were used to distribute the greywater equally where the BTF entrance was at the top. Gravity allowed the greywater to flow from the elevated tank to the BTF. Water might flow by gravity through a regulated exit at the bottom of each BTF column. Perforated pipes were used to distribute water at the BTF column's top properly.

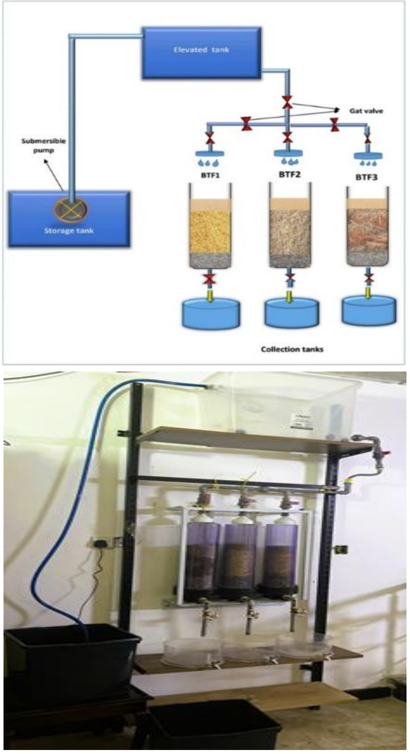


Figure 2. Schematic diagram of the BTF experimental system.

2.4. Substrate Packing Materials

Woodchips (WCH), rice husk (RH), and date palm fiber (DPF) were the three agricultural waste substrates employed in the study in addition to 5 cm of sand layer at the top of the filter as distribution layer and 10 cm gravel layer as drainage in the bottom of the filter as shown in Fig. 3. The substrates were employed after being dried. A comparison of the substrate's pollutant removal capabilities at various heights and contact times was also examined.

Figure 3. Filter section and its gradients for filtering BTF1, BTF2, and BTF3

2.4.1. Woodchips (WCH)

Wood is used as a raw ingredient in procedures that provide wood chips. Because wood is readily available and long-lasting, bioreactors primarily employ it. Because woodchips decompose slowly, they have a decadal lifespan [21]. Owing to this characteristic, Woodchips are classified as a carbon medium with a delayed release. In wood chips, lignin (22-28%), cellulose (40-45%), and hemicellulose (25-40%) in the form of galactomannan make up the majority of the carbon. Fig. 4 shows the woodchips used in this study.

Figure 4. Woodchip used in this study

2.4.2. Rice Husk

After the rice is collected from the rice mill, it is the waste material. This is the most readily available and least expensive material for any kind of goods in our nation. Its nature is one of absorption. It turns hard water into soft water to a certain extent by absorbing contaminants from wastewater. The primary result of milling rice is that rice husk is a significant waste product in the agriculture sector. About 20 weight percent of silica, in an amorphous form, is found in rice husks. Growing demand for silicon composite goods such as zeolite, silicon carbide, silicon nitride, silicon tetrachloride, pure silicon, and magnesium silicide has made rice husk a significant source of raw biomass material [22]. Iraqi rice husk was gathered from southern Iraqi rice farms. Fig. 5 shows the rice husks used in this study.

Figure 5. Iraqi Rice husk

2.4.3. Date palm fibres

This study assesses the utility of date palm surface fiber as a biosorbent for removing contaminants from wastewater, including primary colors, acids, heavy metals, oils, and pesticides. This substance includes organic chemicals and offers advantages. Date palm surface fiber exhibits a vast future on a large scale worldwide, having been widely used for perspectives in several other applications. The natural fiber material known as date palm fiber (DPF) is highly abundant in Middle Eastern countries like Saudi Arabia. It is also an effective biosorbent to remove pollutants from affordable, renewable, eco-friendly, and available water [14], [23]. Fig. 6 shows the date palm fibers used in this study.

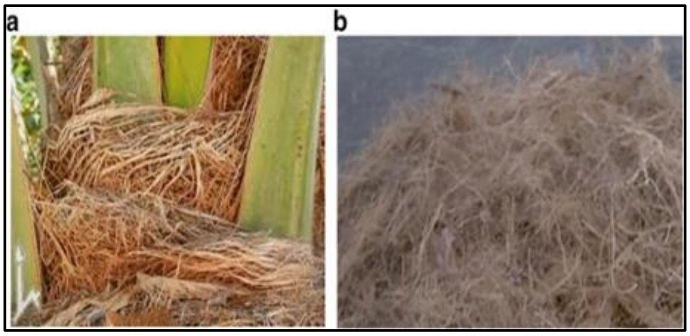


Figure 6. Date palm fibers (a) on tree (b) separated

3. Operating Conditions

Different operating conditions were applied to the biofilter columns, including different 15 cm and 20 cm substrate heights and variable hydraulic retention times across 12, 24, and 48 hours. Pre-treatments involving screening, fats, oil skimming, and sedimentation were considered to minimize the rate of organic matter loading while preventing the filter medium from clogging in this system. The wastewater ought to be pre-treated (by sedimentation) to boost the efficacy of the biofilters throughout filtering. When adding GW to the settling tank, a 1.2-mm screen was employed to reduce the quantity of solids that got into the arrangement. Tee connection and the settling tank's outflow kept suction, oil, and fat out of the filters.

Seven liters of biofilter (r = 7.5 cm) and filter media depth (h = 0.4 m) were operated intermittently in three doses per day while the pilot-scale biofiltration was operating at constant HLR (0.02 m3 m−2 day−1) for the duration of the monitoring period.

The external temperature (room temperature) fluctuated between 25 and 32 °C in all trials, simulating the surrounding temperature in warmer weather settings, whereas the greywater supply remained at 25 °C. Utilizing a hydrograph for greywater production in a typical residence in a rural community in Iraq, the greywater was supplied intermittently in three doses per day at percentages of 70, 10, and 20% of the daily HLR [20]. Since typical on-site treatment systems get their feed from greywater sporadically, this is also the case with greywater generation. Fig.7 shows the methodology of the experimental work diagram.

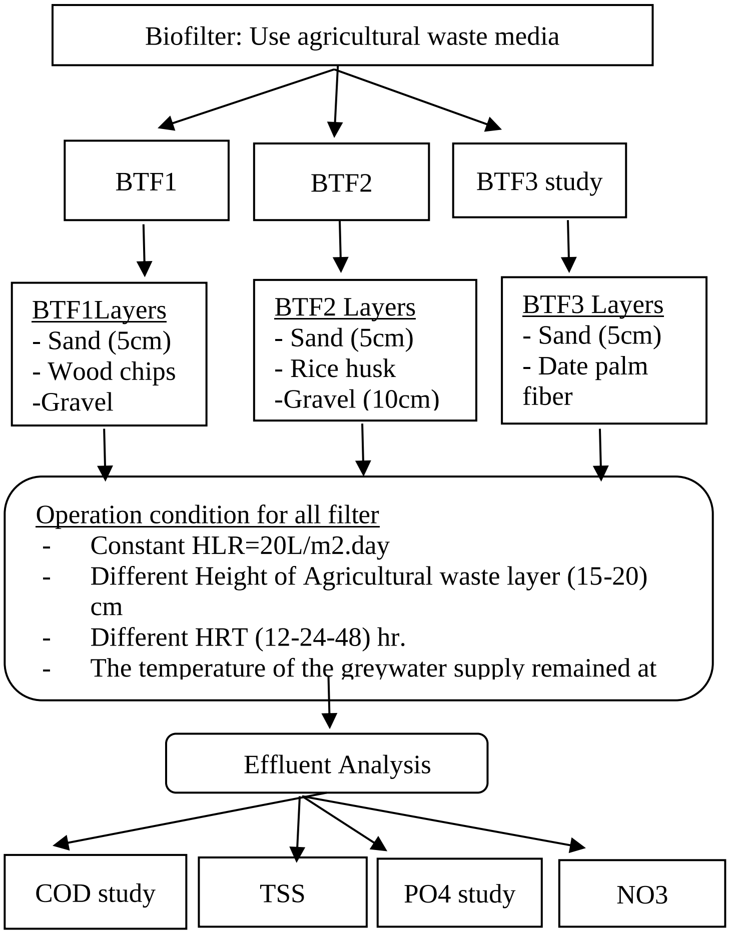


Figure 7. Methodology of experimental work for filter BTF1, BTF2 and BTF3.

4. Sample Analysis

Samples in Fig. 8 were analyzed before and after the treatment to examine the many factors determining the quality of the greywater. One-liter samples from various sources were gathered and subjected to conventional methods and techniques for testing variables, including turbidity, pH, COD, TSS, chlorine, and BOD [24]. A COD digester measured the COD [25]. The effluent of GW, which was considered a recommended standard for irrigation, was compared with the Iraqi standards for reusing greywater for irrigation in 2012. Samples were transferred directly to the laboratory, stored at four °C, and analyzed to avoid contaminants from changing their characteristics.

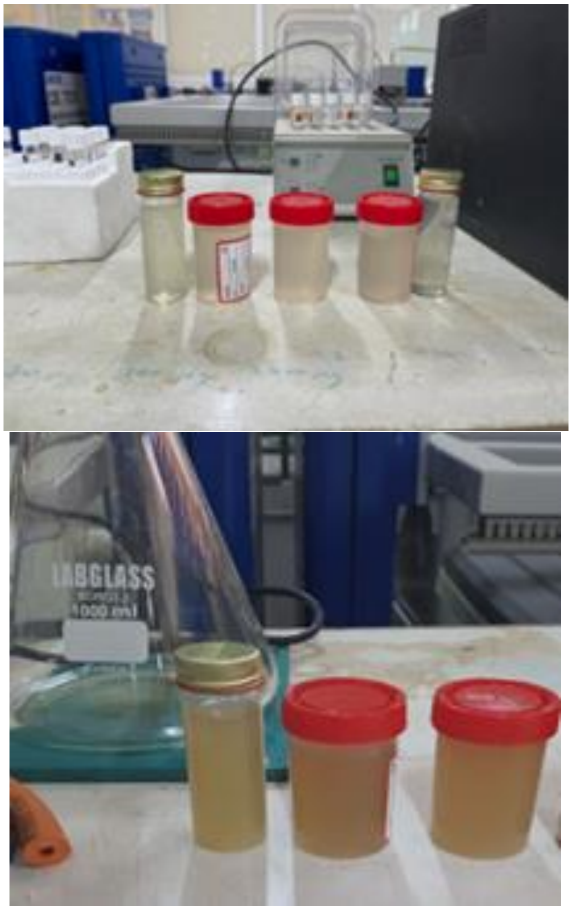


Figure 8 Greywater samples in the laboratory

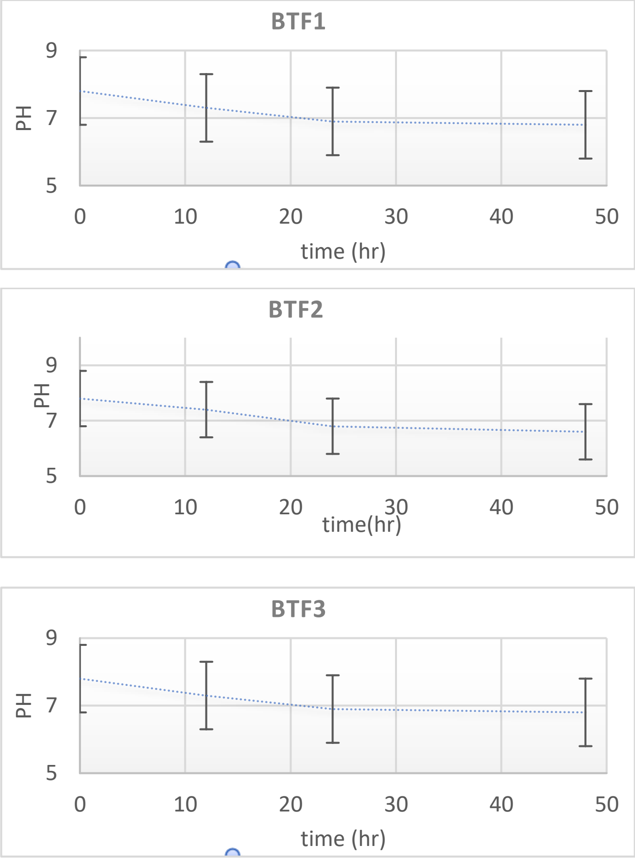


Figure 9. Variation in PH values with contact time

5. Results and Discussion

5.1 The pH variation with time

A multiparameter device was used to measure the samples' pH directly. The average influent's pH varied between 7.3±0.12 and 7.6±0.22, averaging 7.5±0.18. In the filtration columns BTF1, BTF2, and BTF3, no significant pH changes between the influents and effluent across all HRTs. The system exhibited a marginal reduction in pH for filter columns BTF1, BTF2, and BTF3 at 12, 24, and 48 hours. The discharge of organic acids from the filter mediums was the reason for this pH change. The effluents from the tap water-supplied filter had a yellow tinge throughout the tests, indicating the discharge of chemicals[26]. The production of hydrogen ions throughout the nitrification reaction of NH4-N to NO3-N is probably an additional aspect leading to the pH drop[27]. The pH before filtration was found to be 7.8±0.18, and after filtration in filter columns BTF1, BTF2, and BTF3 was found to be 6.7±0.11, 6.6±0.14, and 6.8±0.13, respectively (Fig. 9).

The greywater utilized in this study had a mean pH of 7.9 ± 0.4. The pH values fall between 6.5±0.11 and 8±0.14 [12]. As shown in Fig. 10, the nitrification of NH_4-N to NO_3-N [28] and the release of humic acid (HA) when the biomass media breaks down[29] [30] are the two likely causes of the pH drop in the filters. The acidic conditions in the filters were not low enough for Salmonella and Enterococcus species to become fatal. According to Ramiyeh's [31] observations using the same filter, the pH in the filter never achieved a neutral state during the experiment. The continuous degradation of raw media produces additional HA and causes the pH of the filter to decline steadily. Acidification can be sped up in areas with enough water in the filter system by using agricultural waste media containing humic acid (HA) released in filtered during the decomposition of natural agricultural waste media (wood chips, rice husk, and date palm). The discharge of organic acids from the filter mediums was the reason for the pH change. Saliling et al. [32] found that when wood chips and wheat straws are used as filter media, the deterioration of agricultural waste media can result in a loss of mass and changes in porosity.

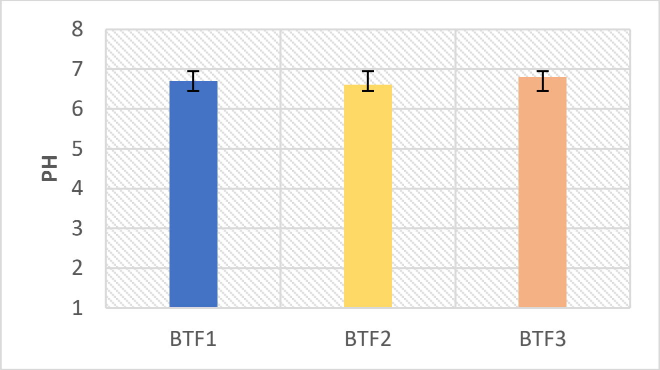
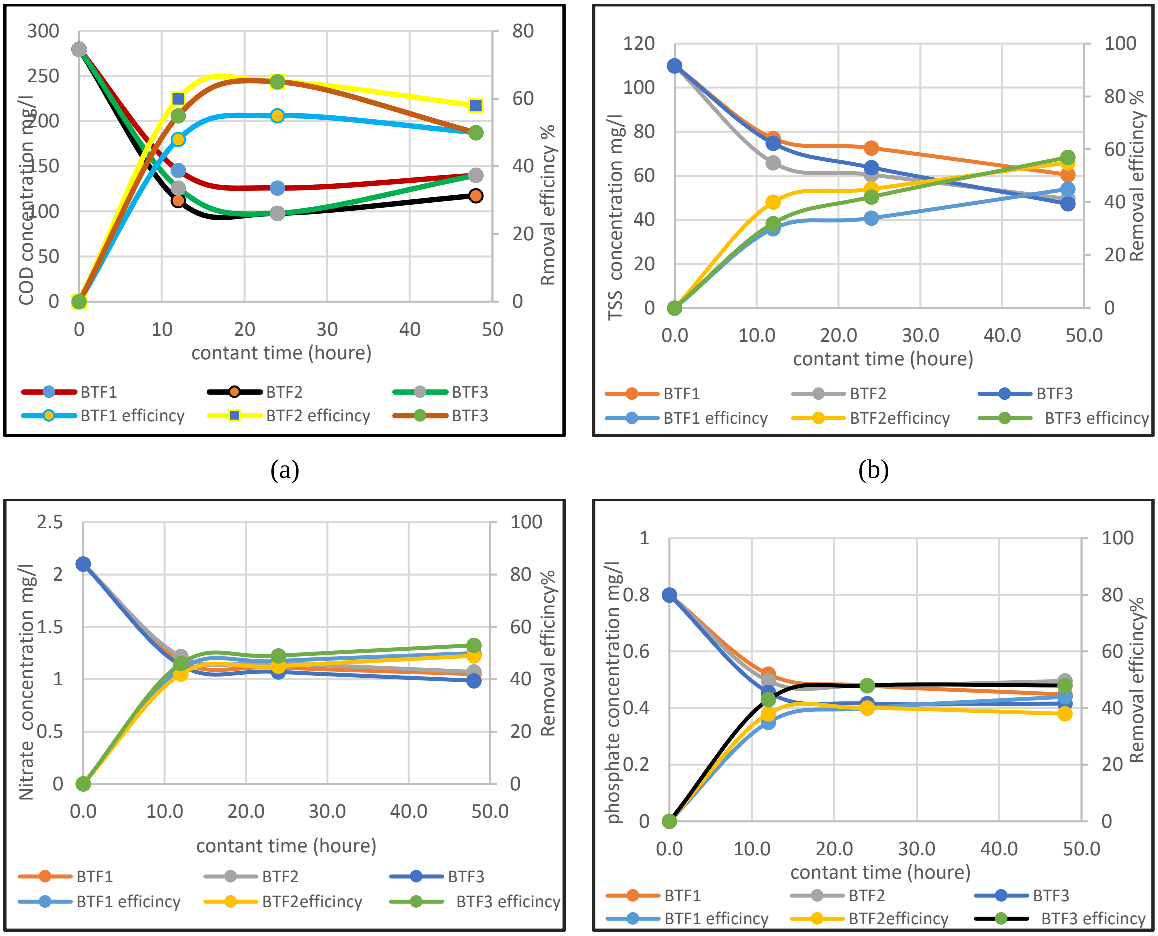


Figure 10. Variation of PH values in the effluent at filter columns BTF1, BTF2, and BTF3

5.2 Organic matter and Nutrient removal

5.2.1 First Run

In the first run, three filter columns (BTF1, BTF2, and BTF3) were parallelly operated at fixed HLRs of 20L/m^2.day and 15 cm height of agricultural waste. The system slightly improved COD, TSS, nitrate, and phosphate. Fig.10 shows the results of influent, effluent, and percentage removal of TSS, COD, BOD, nitrates, and phosphate.



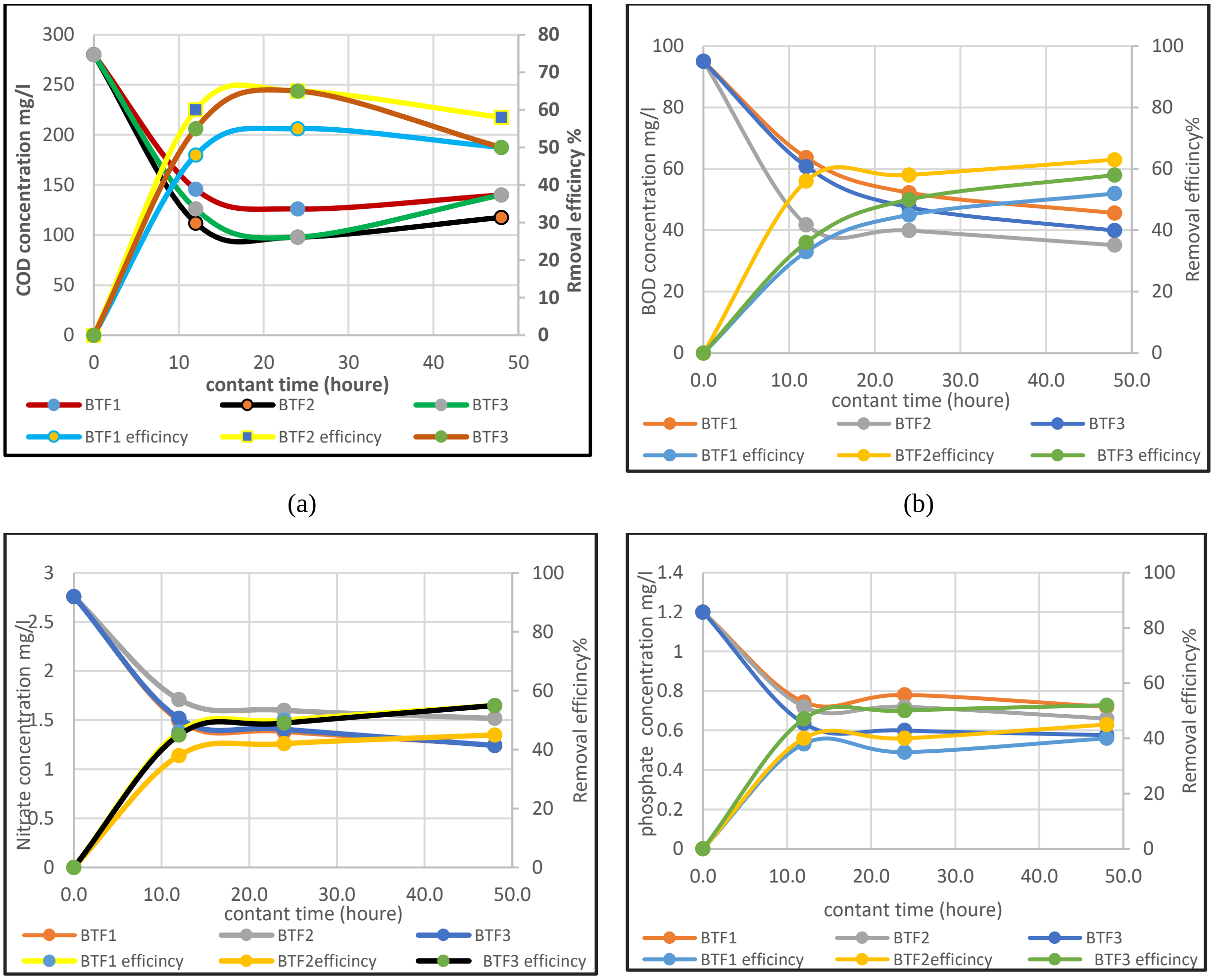
(a) (b)

(c) (d)

Figure 11. Concentration/efficiency removal at 15cm(a) COD (b)TSS (c) Nitrate(d) phosphate

5.2.2. Second Run

During the second run, the three filter columns were operated concurrently with the same hydraulic loading rate (HLR) as in the first run. The agricultural waste height in this run was 20 cm, as shown in Fig.6. The system slightly improved TSS, COD, BOD, nitrate, and phosphate. Fig. 11 shows the results of influent, effluent, and percentage removal of TSS, COD, BOD, nitrates, and phosphate.



(a) (b)

(c) (d)

Figure 12. Concentration/efficiency removal at 20cm(a) COD (b)TSS (c)Nitrat(d) phosphate.

The rice husk media in BTF2 (rice husk) indicated higher removal efficiencies for the greywater contaminants (COD, TSS, NO_3, and PO_4) compared to BTF3 and BTF1 (date palm fiber and wood chip) media in the same depth (20 cm) and optimum contact time (24 hrs.) as shown in Fig. 12. The investigated biofilter medium had removal efficiencies of COD, which were 65.7±5 for rice husk, 63.3±3 for date palm fiber, and 61.6±7.24 for wood chips. Furthermore, the removal efficiency of Total Suspended Solid (TSS) for rice husk, date palm fiber, and wood chips was 77.43, 75.6, and 70.3±3.5, respectively. The NO_3 removal efficiency for rice husk, date palm fiber, and wood chips was 50.21%, 55%, and 45 respectively. In contrast, the percentage of (PO_4) removal efficiency for rice husk was 55.92, 52.52 for date palm fiber, and 42.45 for wood chips—Fig.13.

According to Genç-Fuhrman et al. [33] and Ribé et al. [34], the washing and release of organic acids from the raw material may account for the low reduction of COD in BTF1, BTF2, and BTF3 when compared with BOD5. This low reduction was not seen with the other filters. All ammonia was eliminated during the passage in the BTF1, BTF2, and BTF3 filters. 0.6 to 2.2 mg/L of nitrate was the low and constant input concentration throughout the experiment. An extremely high and highly variable nitrate level was found in the BTF effluents.

The study conducted by Nema et al. [35] found that the effectiveness of removing COD increased as the retention time increased to 12, 24, and 48 hours. However, the removal effectiveness dropped after 18 hours. The study investigated the impact of retention time on various primary media (rice husk, coir jute rope, marble chips, and pine wood) without sand and GAC for treating greywater in India. Furthermore, it was observed that filter column B exhibited greater efficiency than filter column A due to an active site in the molecular structure of GAC, which facilitates the oxidation of organic materials.

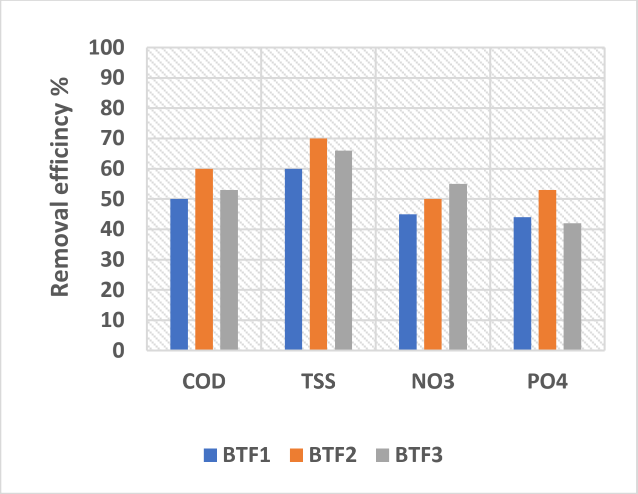


Figure 13. COD, TSS, and nutrient removal efficiency through the three filters.

5.3. Biofilter performance with the most optimal operation conditions

5.3.1. Filter performance concerning retention time

At a steady hydraulic loading rate of 0.15 m/h, the three filter columns (BTF1, BTF2, and BTF3) were run in parallel. The system was initially set up to operate for two weeks to ripen the filter until steady-state conditions were reached when the variations in subsequent measurements of TSS and COD were less than ±1% [36]. Constant hydraulic loading rate maximized the hydraulic retention times of 12-, 24-, and 48-hours Fig. 14. Greywater was kept in the system before the effluent flowed out, ensuring this retention period. Based on the literature, these retention times were taken into account. The efficiency with longer retention times (12 and 24 hours) fell until 48 hours. According to Niwagaba et al. [37], there is a substantial correlation between the reduction of COD and TSS and the retention period of GW in the filtration system. It reduced COD by more than 50% because dissolved organic and inorganic matter stuck to the filter media, and organic matter was chemically broken down [37]. At 12, 24, and 48 hours, there was a significant drop in the numbers of TC and FC in both filter columns after different contact times. This could be because of adsorption onto the filter media, oxidation, and sticking to biofilms; according to additional research on GWT conducted by Niwagaba et al. [37], the effluent findings. After 48 hours, there was a decline in the removal efficiency. This might have happened because the system contained more organic materials after an extended hydraulic loading rate, which aided the microbes' regenerating ability. Regenerating ability. Reductions in COD and TSS allow nitrifying bacteria to use dissolved oxygen to generate new biomass [38].

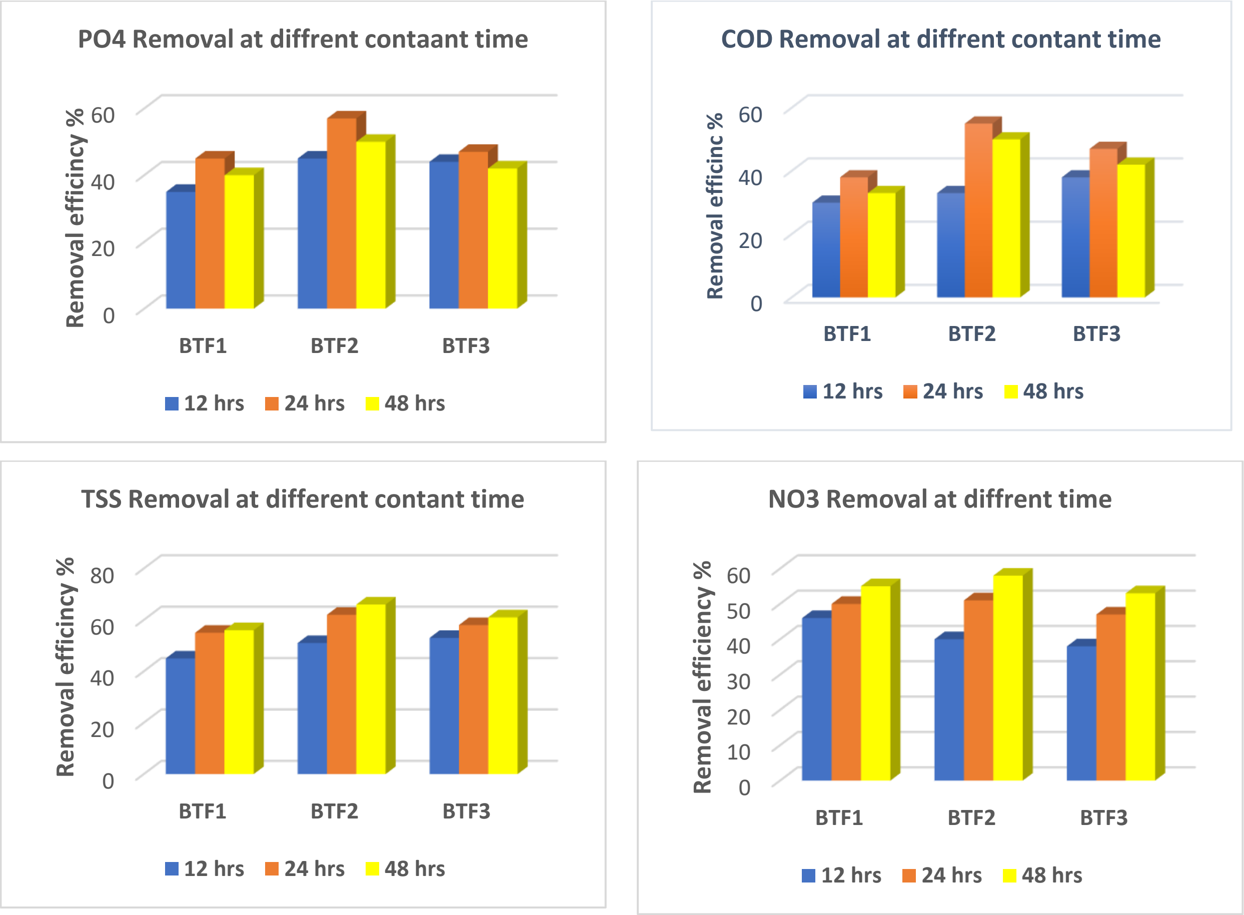


Figure 14. Influence of contact time on the COD, TSS, and nutrient removal.

5.3.2. Filter performance concerning filter height

The removal efficiencies of greywater contaminants (COD, TSS, NO_3, and PO_4) showed higher removal at a depth of 20cm compared with other applied depths for biofilter (BTF1, BTF2, and BTF3) media. The improvement in the removal efficiency at a depth of 20 cm is due to the increase in the total surface area of bio-filter media and the contact time between constituents and filter bed media. [39]. Most organic matter removals occurred in the filters' top 20 cm of agricultural waste depth. The filter media clogging has been recognized as a standard and significant problem affecting the system's hydraulic and treatment efficiencies, especially the long-term performance. The clogging consists of the obstruction of the pore space, and it tends to appear in the upper layer of the sand filter where the substrates and microorganisms are most abundant. The causes of clogging can be related to various factors, such as environmental and operational conditions, which both influence the process. By the nature of the Combined mechanisms, clogging is generally categorized as a physical, chemical, and biological process (biofilm). Physical clogging (caused by organic or inorganic suspended matter that cannot be filtered out in a filter), chemical clogging (caused by the soluble substances in water, such as carbonates, phosphates, and sulfates), and biological clogging (caused by the growth of microbial biomass), in biofilter especially in sand filters [40].

6. Conclusions

The use of agricultural wastes (rice husk, date palm fiber, wood chips) in greywater treatment could be a promising option for municipal wastewater treatment, especially in rural areas that suffer from a lack of sanitation services and have a high amount of these wastes produced annually this option may offer economic and green engineering solution. Different operation conditions are used to treat domestic greywater and reuse it in irrigation to help mitigate the massive water shortage in Baghdad, specifically in rural districts encircling Baghdad, particularly in rural areas with poor sanitation and high waste production annually. This choice might provide a cost-effective and environmentally friendly technical solution. The results indicated that the lowest reduction efficiency for pollutants (COD, TSS, NO3, and PO4) observed at BTF1(wood chip medium) was (61.6%,70 %,45%, and 45.5%), respectively. Rice husk media in BTF2 was the most effective biofilter media, providing the highest removal efficiency for pollutants (of COD, TSS, NO3, and PO4) were (65.7%, 77.43%, 50.21%, and 55.92%) respectively, compared to BTF3 and BTF1 in the same height (20 cm) and optimum contact time (24 hrs.). Rice husks have performed better than date palm fibers and wood chip filters in most treatment parameters. Also, date palm fibers are more prone to damage and decomposition and require constant replacement because the lifespan of these fibers is shorter than that of wood chips and rice husks. In future studies, biochar produced from agricultural waste can be used as a biofilter, an alternative to raw agrarian waste, to reduce the environmental potential negative impacts of frequent filtration media replacement.

Acknowledgments

The authors thank Mustansiriyah University (www.uomustansiriyah.edu.iq) Baghdad-Iraq for its support in the present work.

Conflict of interest

"The authors declare that there are no conflicts of interest regarding the publication of this manuscript."

Author Contribution Statement

Ebtesam K. Abbas proposed the research problem, developed the theory, and performed the computations.

Seroor Atalah K. Ali verified the analytical methods and supervised the findings of this work. Both authors discussed the results and contributed to the final manuscript.

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