Sustainable
Engineering and Technological Sciences
https://sets.zenithacademic.co.uk/index.php/sets/index

Sustainable Engineering and Technological Sciences, 01(01), 2025, pp. 1-13
DOI: https://doi.org/10.70516/34yn7403

ISSN 3049-7787 (Print)
ISSN 3049-7795 (Online)

Comparison of Raw and Pyrolyzed Rice Husk as Bio-Trickling Filters media in Greywater Treatment system

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Article info

Received 12 April 2024

Revised 8 May 2024

Accepted 14 May 2024

Available online 1 Jan. 2024

Keywords: *Rice Husk, Biomass, Bio Char, Greywater, Waste, Porosity.*

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. In this study, a simple, promising, and economical method for on-site greywater treatment is developed, employing agricultural waste as a bio filter medium and using it as irrigation water in rural Iraqi areas. The impact of rice husk biomass waste's pyrolysis and bio char characteristics on greywater treatment was examined using a bio trickling column treatment. Waste biomass from rice husks was paralyzed at 360°C. The pyrolysis of the husk biomass resulted in an increased surface area and pores. COD and BOD removal percentages in BTF2 were 81% and 88%, respectively. BTF1 has a 65% efficiency in COD removal and a 71% efficiency in BOD removal. For BTF1 and BTF2, the corresponding nitrate removal percentages were 52.93% and 75.38%. For BTF1 and BTF2, the respective phosphate removal rates were 45% and 65%. For BTF2, in this study the result show that the filter BTF2 (bio char filter) was the more effected than BTF1 (raw rice husk filter) in removal pollutant from greywater demonstrated a good deal of promise for treating greywater. Limiting the accumulation of agricultural waste and using it as a bio filter media for municipal greywater treatment are essential steps toward ensuring the environmentally safe disposal of agricultural waste in Iraq and reducing the cost of wastewater treatment.

1. Introduction

The bigger sized biochar A cheaper wastewater processing system is needed due to the high cost of installing existing technologies and pre-treating home wastewater. Based on El-Nadi et al. (2014), discharging treated household waste water into rivers is possible after filtering it via crop waste as a bio-packing medium. Although crop wastes are frequently considered to be completely useless, they might cause to environmental damage. Mukundan and Ratnoji (2015) claim that employing crop residue as a renewable resources in wastewater purification processes promotes cleaner operations and waste reduction.

The wastewater generated in the kitchen, laundry, and bathroom is sometimes referred to as grey water. Greywater makes up all of the water that drains from a residence apart from toilet waste [1-3]. Because of growing industrialization and growth, emerging countries have more alternatives for reusing greywater [4]. A population's level of living, total water use, demographics (like gender and age), water infrastructure, and resident behaviors all affect how much greywater it produces [5, 6]. Therefore, greywater makes up between 50% and 80% of the volume of wastewater produced by houses. Greywater flow rates range from 90 to 120 l/p/d on average [7].

According to the literature, the dishwasher and kitchen sink contribute about 24% of greywater. About 49% of the space is occupied by the sink, bathroom, and shower, and roughly 27% is occupied by the laundry and washing machine [8, 9]. The lifestyle decisions made by the population result in the production of grey water [10, 11]. Its characteristics are therefore very erratic and influenced by the cultural and social contacts, lifestyles, water accessibility, and levels of consumption of the locals [12]. In addition to E. coli, inorganic ions, heavy metals, and suspended solids, greywater also contains a variety of organic compounds [12, 13]. Despite the common belief that these pollutants are more prevalent in wastewater, multiple studies have revealed the exact opposite to be true in greywater. [14]. the many characteristics of greywater vary depending on the season, day time, and quantity and quality of water. Gray water reclamation and reuse should adhere to four criteria: financial sustainability, environmental toleration, sanitary security, and aesthetic attractiveness [15]. Because they have varying needs for water quality, the various reuse uses require distinct treatments [16, 17], ranging from simple to more complex ones. The most effective and realistic method of treating greywater is to combine physical filtration with an aerobic biological process. For urban residential buildings, the multimedia bio filter’s biological trickling filter is a viable option [18].

The goal of this research is to examine how well agricultural wastes (rice husk and bio char made from agricultural wastes) work as packing media and biofilm material carriers for the bio-filtration method of household greywater treatment. In bio-filtration, contaminants are hydrolyzed and broken down by the supported live organisms that develop on the packing media's surface while the water passes through the media. Due to its cheap maintenance costs and efficacy in eliminating organic debris that degrades, bio-filtration is gaining popularity as a water treatment technique [19]. The goals of this study are to assess rice husk's suitability as a natural bioreactor packing material and to develop an affordable continuous bio-filtration system.

One example of a waste-based adsorbent material is bio char made from rice husks. Bio char is a material created by organic materials’ thermal decomposition from forestry and agricultural wastes (refereed as biomass) in the pyrolysis process (i.e., absence of oxygen). For soil conditioning and carbon sequestration, it is frequently employed as a fertilizer [18, 20]. However, because of its high porosity, reactive surface functional group, and surface area, recent investigations have shown that it has potential as an adsorbent in wastewater treatment [21, 22]. For example, storm water [23], municipal wastewater [24], agricultural wastewater [25], and industrial wastewater [26] have all been treated with bio char. In order to eliminate organic and inorganic water contaminants, numerous treatment approaches for greywater treatment have included biochar as a filter material [27-29]. Due to our particular circumstances, Iraq no longer reuses its water resources. Because Iraq is among the nations that have cheap, plentiful sources of clean water to meet our everyday need the majority of Iraqi homes have a little garden or flowerbed, which they maintain with thousands of gallons of water each week to keep green. Many Iraqi citizens engage in urbanized agriculture and food plantation operations as a pastime or to improve the safety of their food. Prices may rise as a result of the low water levels and increased pollution in Iraqi rivers, making efficient water usage more crucial for households, companies, and farmers alike. Wastewater utilization is rising swiftly as a result of interest in reuse technology.

The main objective of the study was to present comprehensive data regarding the efficacy of straightforward, reliable, and affordable alternatives for the on-site treatment of greywater. This work's primary goal is to assess the effectiveness of bio filters using various agricultural waste media, such as rice husks and biochar, which are abundant but not commercially viable in many areas. The purpose of this study was to evaluate and compare the reductions in nitrogen, turbidity, TDS, COD, phosphate, BOD5, and specific microorganisms that several multimedia bio filters induced in greywater. The main goal is to evaluate appropriate small-scale greywater treatment filters so that water for agricultural irrigation can be considered.

2. Material and methods

2.1. Description of the Research Area

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

Table 1. Production of greywater in the research area

Fixtures	%	Amount (L/cd)
Wash Basin	17	27
Bathroom	56	90
Laundry	15	24
Kitchen sink	12	20
Total	100	161

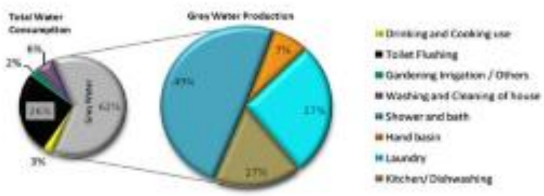


Figure 1. produced greywater in the current study.

2.2. Collection and characterization of greywater

Several sources of greywater were identified, such as laundry, washbasins, kitchen sinks, and post-shower water. After being eliminated from the primary wastewater gathering stream, the drainage pipes from those sources were set up to funnel their flow into individual 5-liter tanks. The research aimed to characterize various greywater sources of or the specific locations where greywater is produced, as previously mentioned. The samples were extracted from the collection tanks and subjected to laboratory analysis in order to determine the concentrations of various parameters. Table 2 presents the characteristics of the gathered greywater sample and its comparison to the standards set by Iraq.

Table 2. Properties of the collected greywater sample

Parameter of Column A	Units	Mean±Std (Before Filtration)	Iraqi Standard
pH	–	7.9 ± 0.4	(6.5-8.5)
Temp.(Ċ)	(Ċ)	23.5 ± 0.3	-
Turbidity	NTU	210.5 ± 10.6	
EC	µs/cm	922.5 ± 232.6	
(TDS)	mg/l	456.5 ± 117	1500
BOD5	mg/l	180 ± 40	
COD	mg/l	290 ± 50	<100
TSS	mg/l	187 ± 50	
Po4	mg/l	1.15 ± 0.8	
NH4-N	mg/l	25.65 ± 5.4	
Nitrates	mg/l	3.5 ± 2.5	
K^{+1}(mg/l)	mg/l	13.4± 0.4	100
Na^{+1}(mg/l)	mg/l	134.8 ± 4.5	250
Ca^{+2}(mg/l)	mg/l	215.8 ± 5.4	450
Mg^{+2}(mg/l)	mg/l	155.8 ± 0.4	60
SAR	Meq/l	0.8 ± 0.25	
$CaCO_3$(mg/l)	Mg/l	15.8 ± 0.4	300
So_4^{-2}(mg/l)	Mg/l	58.8 ± 10	200
Fecal Coliform	CFU/100ml	80000	-
Total Coliform	CFU/100ml	95000	-

2.3. Experimental setup

The pilot-scale of the bio-tickling filter was carried out in-house. Figure 2 depicts the schematic diagram of the RHF experimental system (the system was chosen following a review by Tusiime, Solihu [30].

The treatment system consisted of three stacked columns named BTF1 and BTF2,(the third one was using in second run for the same filters to experment diffrent operation conditions(height of media)), each with an inner diameter of 15 cm and a total height of 50 cm. The gravity flow of raw greywater into the elevated tank was made possible by positioning the elevated tank on a platform constructed higher above the reactor column filters. In order 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 RHF levels with gray water during the experiment.

Figure 3.1 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 utilized to distribute water at the top of the BTF column properly.

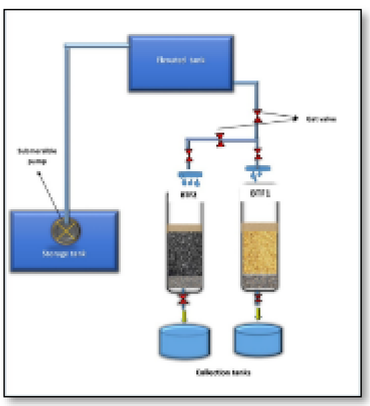


Figure 2. Schematic diagram of the BTF experimental system.

2.4. Substrate Packing Materials

2.4.1. 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 waste water. The primary result of milling rice, 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 major source of raw biomass material. [26]. Iraqi rice husk was gathered from southern Iraqi rice farms. Figure 3 shows the rice husks and their properties.

Bulk density (kg/m^3)	**96-160**
Sulphur (%)	0.04-0.08
Ash (%)	22.0-29.0
Hardness (mohr scale)	5-6
Oxygen (%)	31.0-37.0
Hydrogen (%)	4.0-5.0
Length of husk(mm)	2-5
Nitrogen (%)	0.23-0.32
Carbon (%)	35.0
Moisture (%)	8.0-9.0

Figure 3. Rice husk utilized in the current study

2.5. The RH Bio char preparation

Washing the rice husk three times with distilled water was done. Once the soluble components from the rice husk were extracted using additional distilled water, the adsorbent was dried at 105°C for a whole day to return to its original piece size. The sample is placed in an iron box, dried for eighteen hours at 105 oC, and then pyrolyzed for one hour at 360 C in an electrical furnace (Carbolite CWF1200/UK). As shown in Figure 4.

Figure 4. Schematic diagram showing biochar production in a slow pyrolyzer.

2.6. Sand and gravel media

A sand collection station in the city provided the gravel and sand for the filter medium. Before using it, tap water was used to wash it until clear water was visible. The function of the gravel was drainage. Sand was chosen as the distribution layer because it was readily available and in comparison to filter media such as sawdust, rice husks, and pine barks, it removed contaminants from low-strength wastewater with a high degree of effectiveness [31].as show in Figure 5

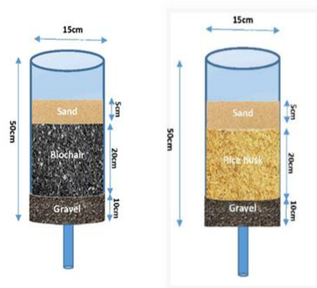


Figure 5. Filter section and its gradients for filtering BTF1 and BTF2

3. Operating conditions

The effluent exited the reactor through the bottom while the raw graywater was injected into the reactor's upper end. In each step, the three filter columns were run in parallel at a steady 0.15 m/h hydraulic loading rate (HLR). The various substrates' effectiveness was evaluated under contact periods (12, 24, and 48 hours) and substrate heights (15 and 20 cm). The HLR was calculated using the design standards outlined in the EPA [32] handbook and previous studies on treatments of greywaters [31]. The systems were initially set to operate for 14 days in order to allow the filter to mature and reach steady-state conditions. Figure 6. showing Methodology of experimental work for filter.

Depth	**Rice husk Filter (RHF-1)**	**Bio Char Filter (RHF-2)**	
15 cm	12 / 24 / 48	12 / 24 / 48	1st Run
20cm	12 / 24 / 48	12 / 24 / 48	2nd Run

Figure 6. Methodology of experimental work for filter

4. Sample analysis

Samples in Figure 7 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 [29]. A COD digester measured the COD [33].

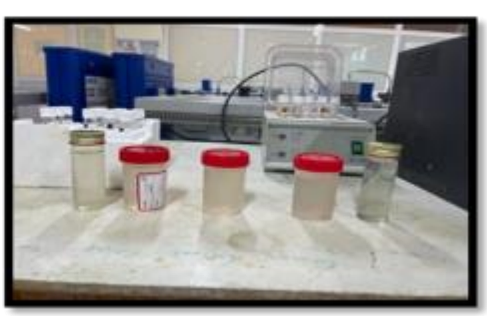


Figure 7. Greywater samples

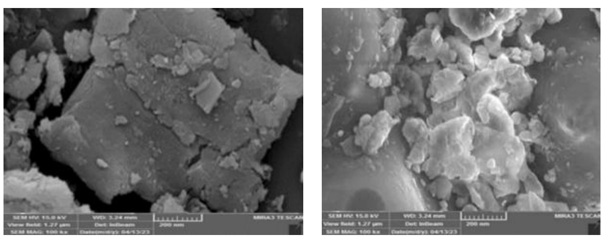
5. Results

5.1. Physical characteristics of of Bio char(RHB)

The rice husk biochar had a basic pH of 10.61. The pyrolysis of the biochar, which changed its structural shape and raised its ash content, may be the cause of the biochar's basic pH. In addition, carbonization reduces acidic functional groups and promotes the synthesis of carbonates and inorganic alkalis [34]. Similar research on coconut husks have reported pH values within the same ranges [35]. The rice husk appears to have a higher bulk density and porosity than thebiochar, indicating a comparatively higher throughput. The moisture content of the rice husk was 5.7%, whereas the biochar was 5.6%. Biochar might have a lower moisture content than other materials because of the thermal action, which helps to evaporate volatile organic compounds and water. The specific surface area of rice husk material is quite low, at 2.2 m2/g, but the maximum specific surface area was found in rice husk char that was pyrolyzed at 360 °C, with 101.295 m2/g.

5.2. Microscopic Imaging (SEM)

The pore structure and morphology of the RH and RHB differ, as seen in the SEM images in Figure 8. With diverse cylindrical pores, the RH has a clear fibrous structure. Following carbonization, the carbon-containing adsorbent's links in the microstructure are shown to be broken. Suman and Gautam [36] observations are followed by this. Because of the lignin and cellulose components' breakdown at high temperatures during pyrolysis, the RHB exhibits comparatively more pores and additional surface area. According to reports, the maximum surface area happens at 400°C [37]. Higher pores give adsorbates enough places to store in the adsorbents' interstitial spaces. More surface area is also required for more areas where pollutants can be adsorbed. The SEM images show that the RH's qualities are improved after charring, and the RHB has a comparatively higher capability for pollutant removal than the RH due to its larger pore diameters and surface area.



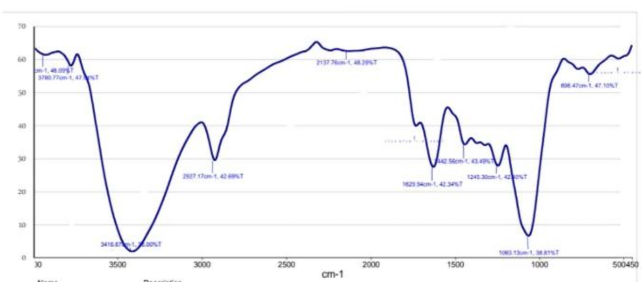
(a) (b)

Figure 8. SEM images were taken of (a) Rice husk samples (b) bio char from rice husk

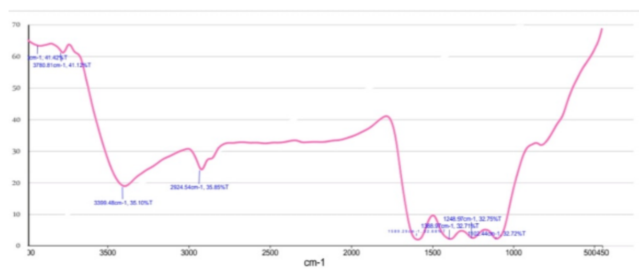
5.3. Fourier transform infrared (FT-IR) spectroscopy

Figures 9 display the FTIR analysis of the investigated adsorbents. The raw rice husk's FTIR spectra, depicted in Figure 9, exhibits peaks at approximately 2925.8 cm^{-1} (C-H groups), 3404.3 cm^{-1} (-O-H groups), 1080 cm^{-1} (Si-O-Si group), 1379.0 cm^{-1} (aromatic CH stretching and carboxyl-carbonate structures), 1546.8–1652.9 cm^{-1} (C = C groups), 1641.3–1737.7 cm^{-1} (C = O group), 1380 cm^{-1} (CH_3 group), 1461.9 cm^{-1} (CH_2 and CH_3 groups), 1238 cm^{-1} (CHOH group), 1153.4–1300 cm^{-1} (CO group), and 862.1–476.4 cm^{-1} (Si-H group) [2, 38].

The biochar's FTIR spectrum demonstrates As with aromatic carbon, a few pairs of typical peaks emerged more distinctly, including C=C (1380–1450 cm^{-1}), C–H stretching (750–900 cm^{-1} and 3050–3000 cm^{-1}), and C–C and C–O stretching (1580–1700 cm^{-1}). The charring temperature alters the functional group, as indicated by the infrared spectra; as a result, aromatic C increases while aliphatic 25 C groups decrease. Given that the duration of biochar varies depending on how it is produced [39].



(a)



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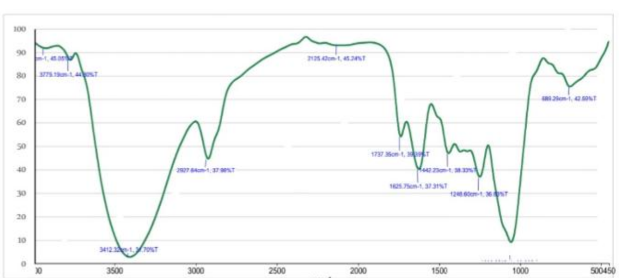

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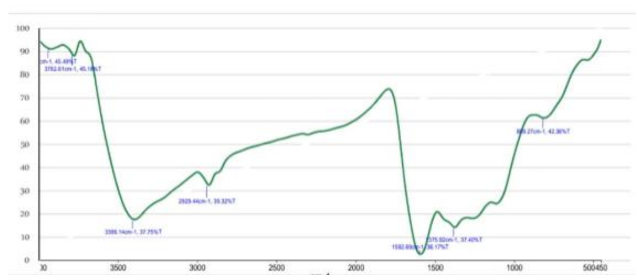


(d)

Figure 9. FTIR analysis (a)raw rice husk befor treatment (b)raw rice husk after treatment (c)biochar befor treatment(d) biochar after treatment

5.4. Removal efficiency of Filters(RHF-1 ,RHF-2)

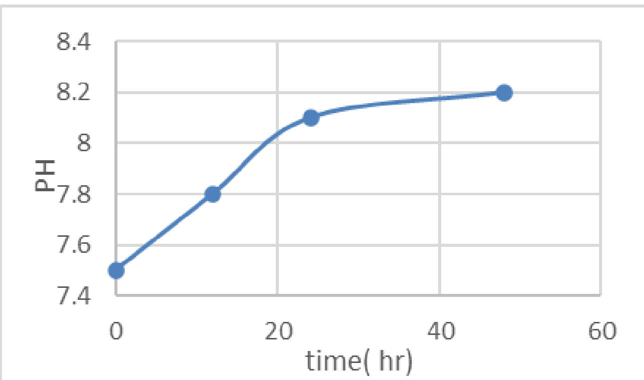
The influent's pH varied between 7.3 and 7.6, with an average of 7.5 ± 0.18 (SD). For filter column RHF-1, the system lowered the pH by 1.3%, 2.7%, and 2.7%. The nitrification that occurred in the settling tank may be the cause of the pH drop following the tank.as show in figure 10 (a). The PH of the effluent via the BTF2 column beds rose to 8.2. As shown in Fig. 10 (b), Because of the creation of inorganic alkalis and carbonates during carbonization, it has been shown that the pH of the biomass feedstock increases, making biochar usually alkaline. carbonization also reduces acidic functional groups. In turn, this causes charcoal to release OH ions upon contact with water, raising pH. While reducing the acidic functional groups, carbonization promotes the synthesis of inorganic alkalis and carbonates. All PH effluent value was in the Iraqi standerd .

5.4.1. At First Run

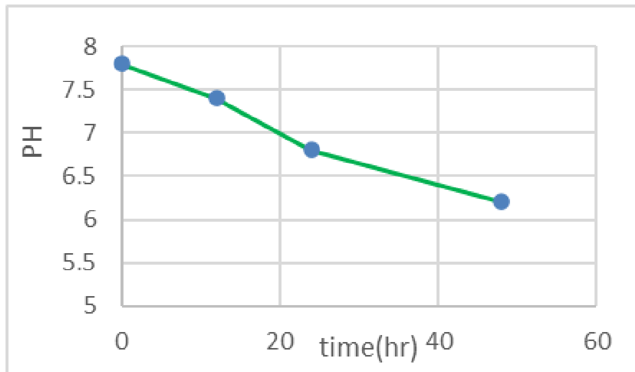
In this run, two parallel filter columns were run at a 0.15 m/h hydraulic load rate (HLR) of, with agricultural waste in its natural form positioned at a height of 15 cm, as well as in layers with 5 cm of sand and 10 cm of gravel. TSS, COD, BOD, phosphate, and nitrate levels in the system indicated a minor improvement. The following figure displays the influent, effluent, and percentage removal of TSS, COD, BOD, phosphate, and nitrates. Table 2 and 3.

5.4.2. Second Run

In this run, two parallel filter columns were run at a steady hydraulic loading rate (HLR) of 0.15 m/h, with agricultural waste in its original state at a height of 20 cm, as well as in layers with 5 cm of sand and 10 cm of parameter unit before filtering (Table 4 and 5).



(a)



(b)

Figure 10. influent's pH varied with time for (a) BTF1 (b) BTF2

Table 2. Greywater analysis previous to and following filtration by RHF-1 at 15 cm rice husk height

Parameter	Unit	Before Filtration Mean±Std	After Filtration At 12hr Mean±Std	After Filtration At 24hr Mean±Std	After Filtration At 48hr Mean±Std	Iraqi Standard
PH	–	7.9 ± 0.4	7.3 ± 0.4	7.35 ± 0.2	6.5 ± 0.1	(6.5-8.5)
TDS	Mg/l	456.5±117	380±1.4	365±38.2	341.5±118.1	1500
BOD5	Mg/l	180 ± 40	20.7 ± 1.0	62.2 ± 1.4	71.5 ± 2.1	
COD	Mg/l	290 ± 50	174 ± 1.4	104 ± 2.1	87 ± 4.2	<100
TSS	Mg/l	187 ± 50	97.24 ± 1.4	59.84 ± 1.4	41.14 ± 1.4	
PO4	Mg/l	1.15 ± 0.8	0.92 ± 0.1	0.8 ± 0.1	0.65 ± 0.2	
NITRATES	Mg/l	3.5 ± 2.5	2.45 ± 1.4	1.9 ± 1.4	1.57 ± 2.3	
TOTAL COLIFORM	CFU/100ml	95000	5800 ± 283	43000 ± 4242.6	477500 ± 3535.5	

Table 3. Greywater analysis previous to and following filtration by RHF-2 at 15 cm rice husk height

Parameter	**Unit**	**Before Filtration Mean±Std**	**After Filtration At 12hr Mean±Std**	**After Filtration At 24hr Mean±Std**	**After Filtration At 48hr Mean±Std**	**Iraqi Standard**
PH	–	7.9 ± 0.4	7.3 ± 0.4	7.35 ± 0.2	8.5 ± 0.1	(6.5-8.5)
TDS	Mg/l	456.5±117	380±1.4	365±38.2	341.5±118	1500
BOD5	Mg/l	180 ± 40	20.7 ± 1.0	62.2 ± 1.4	71.5 ± 2.1	
COD	Mg/l	290 ± 50	174 ± 1.4	104 ± 2.1	87 ± 4.2	<100
TSS	Mg/l	187 ± 50	97.24 ± 1.4	59.84 ± 1.4	41.14 ± 1.4	
PO4	Mg/l	1.15 ± 0.8	0.92 ± 0.1	0.8 ± 0.1	0.65 ± 0.2	
NITRATES	Mg/l	3.5 ± 2.5	2.45 ± 1.4	1.9 ± 1.4	1.57 ± 2.3	
TOTAL COLIFORM	CFU/100ml	95000	5800 ± 283	43000 ± 4242.6	477500 ± 3535.5	

Table 4. Greywater analysis previous to and following filtration by RHF-1 at 20 cm rice husk height

Parameter	**Unit**	**Before Filtration Mean±Std**	**After Filtration At 12hr Mean±Std**	**After Filtration At 24hr Mean±Std**	**After Filtration At 48hr Mean±Std**	**Iraqi Standard**
PH	–	7.9 ± 0.4	7.3 ± 0.4	7.35 ± 0.2	6.5 ± 0.1	(6.5-8.5)
TDS	Mg/l	456.5±117	380±1.4	365±38.2	341.5±118.1	1500
BOD5	Mg/l	180 ± 40	20.7 ± 1.0	62.2 ± 1.4	71.5 ± 2.1	
COD	Mg/l	290 ± 50	174 ± 1.4	104 ± 2.1	87 ± 4.2	<100
TSS	Mg/l	187 ± 50	97.24 ± 1.4	59.84 ± 1.4	41.14 ± 1.4	
PO4	Mg/l	1.15 ± 0.8	0.92 ± 0.1	0.8 ± 0.1	0.65 ± 0.2	
NITRATES	Mg/l	3.5 ± 2.5	2.45 ± 1.4	1.9 ± 1.4	1.57 ± 2.3	
TOTAL COLIFORM	CFU/100ml	95000	5800 ± 283	43000 ± 4242.6	477500 ± 3535.5	

Table 5. Greywater analysis previous to and following filtration by RHF-2 at 20 cm rice husk height

Parameter	**Unit**	**Before Filtration Mean±Std**	**After Filtration At 12hr Mean±Std**	**After Filtration At 24hr Mean±Std**	**After Filtration At 48hr Mean±Std**	**Iraqi Standard**
PH	–	7.9 ± 0.4	7.3 ± 0.4	7.9 ± 0.2	8.1 ± 0.1	(6.5-8.5)
(TDS)	Mg/l	456.5±117	380±1.4	365±38.2	341.5±118.1	1500
BOD5	Mg/l	180 ± 40	20.7 ± 1.0	62.2 ± 1.4	71.5 ± 2.1	
COD	Mg/l	290 ± 50	174 ± 1.4	104 ± 2.1	87 ± 4.2	<100
TSS	Mg/l	187 ± 50	97.24 ± 1.4	59.84 ± 1.4	41.14 ± 1.4	
PO4	Mg/l	1.15 ± 0.8	0.92 ± 0.1	0.8 ± 0.1	0.65 ± 0.2	
NITRATES	Mg/l	3.5 ± 2.5	2.45 ± 1.4	1.9 ± 1.4	1.57 ± 2.3	
TOTAL COLIFORM	CFU/100ml	95000	5800 ± 283	43000 ± 4242.6	477500 ± 3535.5	

6. Discussion

6.1. Raw greywater Characteristics

The greywater utilized as an influent had varying pollutant concentrations, ranging from intermediate (about 20 mg NO3-N L^{-1}, 0.8 mg PO_4 L^{-1}, and250 mg COD L^{-1}) to high (around 350 mg COD L^{-1}, 10 mg NO3-N L^{-1}, and 4 mg PO_4-P L^{-1}) (Table 2). Variations in the organic matter concentration for greywater, or wastewater from showers, laundry, and kitchens, were reflected in variations in the influent quality [12]. In water-rich and water-scarce regions, wastewater production may differ, which could be reflected in these disparities [38, 40]. Greywater properties, however, differ depending on several variables, including the amount of water used, domestic activities, and the personnel who use the system [20]. rural areas, especially in places with limited water resources, generally generate more concentrated effluent than urban areas with large-scale wastewater treatment plants [38]. Gray water in the sewage system is currently at an average temperature of 20°C in temperature. In this research work, the temperature of gray water was discovered to be 24°C before filtration and 23°C after filtering. It increases by 20°C over the summer and can be an excellent substitute energy source [41]. The biofilter reactors were tested at two distinct depths of 15 and 20 cm.

6.2. Filter Performance

6.2.1. pH changes

From an influent pH of 6.73, the greywater the RHF-1 column bed effluent dropped to 6.27, whereas the RHF-2 column bed effluent rose to 8.2. These modifications mirror the acidity and alkalinity of RHF-1 and RHF-2, respectively, as shown in Figure 10. Biochar is often alkaline because carbonization produces carbonates and inorganic alkalis, that elevate the pH of the feedstock from biomass. Investigation by Belhachemi, Khiari [42] indicates that acidic functional groups might be reduced by carbonization as well.

In turn, this causes charcoal to release OH ions upon contact with water, raising pH. While reducing the acidic functional groups of Table 2, the carbonization process promotes the synthesis of carbonates and inorganic alkalis. Features of the feedstock's physicochemical and biological composition [34].

For both RHF-1 and RHF-2 effluents, pH correction may be necessary depending on the intended use. By considering the RHF-1adsorbent pH of 6.67,8.61 for the RHF-2, and the effluent pH, it is reasonable to infer that the adsorbents changed the acidity and alkalinity throughout the treatments of the effluents depending on their dominant pH. As a result, biochar-treated effluents often have a pH that is greater than that of non-biochar-treated effluents (Emslie, 2019).

6.2.2. Removal of COD, BOD and nutrients

Greywater pollutants (BOD, COD, PO4, and TSS) were removed more effectively at a depth of 20 cm as compared to 15 cm for bio filters (RHF-1 and RHF-2). Compared to RHF-1, RHF-2 had a comparatively greater organic matter removal efficiency (Figure 6). For RHF-2, the percentages of COD and BOD removed were 88% and 70%, respectively. RHF-1 had a COD removal effectiveness of 65%, while RHF-2 had an 81% COD removal efficiency. When compared to RHF-1, RHF-2's COD elimination demonstrated notable differences. Even so, RHF-1 was able to eliminate suspended solids. The formation of microbial communities is facilitated by raw rice husk. However, as lignocellulose in rice husk breaks down over time due to microbial breakdown, as described by Dalahmeh [43], The ability of the microbial populations to eliminate COD and BOD is significantly diminished. Because pyrolysis modifies the chemical character of biochar carbons, rendering them relatively resistant and stable to biological degradation, there was no detected microbial breakdown of biochar in the instance of RHF-2 [44].

For RHF-1 and RHF-2, the nitrate removal percentages were 52.93% and 75.38%, respectively (Figure 7). The RHF-2 had a 20% greater proportion of removal than the RHF-1 did. The husk carbonization may have improved the husk's adsorptive capacity and sites, raised the C:N ratio, and stimulated denitrifying bacteria activity, which could be the cause of the variations [45] expected that biochar carbonized at 600°C would remove material at a rate lower than this. Nonetheless, the rate of removal aligned with research conducted by Halfhide, Lalgee [45], which revealed that nitrate was removed between 74% and 90% from both wastewater and stock solution.RHF-1 and RHF-2 had phosphate removal rates of 45% and 65%, respectively (Figure 7).

6.2.3. Microbial populations

The wastewater stream's microbial loads were significantly decreased by the biochars (Figure 11). The RHF-1 removed two orders of magnitude less fecal coliform (FC) logarithmically than the RHF-2 did. Total and fecal coliform removal for RHF-2 was 2.87 log units, while the control filter's total coliform (TC) removal was 0.31 log units. This backs up the claim that biochar filters remove more coliforms, or Ecoli, from water [46]. According to earlier research, depending on starting counts, log removal for E. coli ranged from 0.1 to 1.0 log units. Even though the results of this investigation support the published figures, a comparatively larger amount of log removal was seen. The increased elimination seen in this investigation The study's increased removal rate could be explained by the characteristics of the biochar and the different types of biochar feedstock [47]. The bigger sized biochar particles contribute to the microbial eradication process via absorption even more, due to their increased contact with the wastewater and more surface areas (Guan et al., 2020).

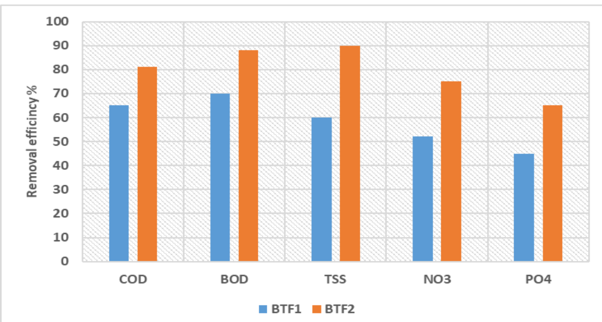


Figure 11. COD, BOD , TSS and nutrient removal efficiency through the three filters.

6.3. Biofilter performance at optimum condition

6.3.1. Filter performance vs retention times

The bigger-sized biochar running in parallel, the two filter columns (RHF-1 and RHF-2) had a constant hydraulic load rating of 0.15 m/h. A continuous hydraulic load rating was used to maximize the hydraulic retention times of 12, 24, and 48 hours. In order to ensure this retention time frame, greywaters were retained in the system prior to effluent discharge. The scientific literature was taken into account while estimating these retention times. Efficiency was indicated to rise with longer retention durations (12 and 24 hours), although it ultimately dropped till 48 hours. In accordance with Niwagaba, Dinno [48], there is a substantial correlation between the reduction of COD and TSS and the amount of time greywater is kept in the filtering system.

Due to the adsorption of dissolved organic and inorganic substances on the filter media, intra-particle diffusion , and chemical oxidation of organic matter, the system dramatically reduced COD (> 50%) [48]. At 12, 24, and 48 hours, respectively, for both filter columns. Through chemical oxidation of organic matter and intra-particle diffusion, the system significantly decreased COD (> 50%) [48]. At 12, 24, and 48 hours for each of the two filter columns, in that order. There are several possible explanations for the significant decline in TC and FC counts in both filter columns at different HRT (12, 24, and 48 hours), including adsorption onto filter media, oxidation, predation, adhesion to biofilms, and natural die-off of microorganisms in the influent. Further studies on greywater treatment by Niwagaba, Dinno [48] and Katukiza, Ronteltap [49] state that The effluent data were mediocre. The removal efficiency began to decrease after 48 hours. This might have resulted from an increase in organic materials in the system after prolonged HRT, which supported the bacteria' capacity for regeneration. TSS and COD decreases enable nitrifying bacteria to exploit dissolved oxygen to produce fresh biomass [50]. Every filter column at 12, 24 hours. according to that sequence. The amounts of NH4, NO3, and PO4 in the filter columns were substantially higher than those in the input.

6.3.2. Evaluate the filter performance with respect to filter height

Greywater pollutants (COD, TSS, NH4-N, PO4, and BOD5) were removed more effectively at a depth of 25 cm when compared to 15 cm when using RHF-1 and RHF-2 media. The enhancement of the removal effectiveness at a depth of 25 cm can be attributed to the augmentation of the biofilter media's total surface area and the duration of components' contact with the filter bed media. According to Dalahmeh [43], the upper 25 centimeters of the filters' depth were where the majority of the organic matter removal took place.

7. Conclusions

As a filter material for greywater treatment, rice husk biomass has a lot of promise. By effectively using pyrolysis on rice husk, greywater treatment was greatly enhanced. Barely 5% of the turbidity was eliminated thanks to RHF-2. 81% COD elimination efficiency was found with RHF-2. With a nitrate removal efficiency of 75.38% versus 52.93% for RHF-1, RHF-2 outperformed RHF-1 in this measure. In terms of eliminating color, turbidity, COD, BOD, and nitrates, empirical data indicates that RHF-2 performed better. According to the SEM image, the adsorbent's surface area and pore count were both enhanced by the carbonization of the raw coconut husk. Two orders of magnitude greater than that of RHF-1, RHF-2 removed logs of faecal coliform. The RHF-2 demonstrated efficacy in managing microbial loads as well. The findings show that pyrolyzed rice husk wastes are a potential absorbent that can be used to treat greywater.

Acknowledgements

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

Conflict of interest

The authors declare no conflicts of interest regarding the current research.

Author Contribution

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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