

# Effect of plant filtration medium on environmental properties of domestically generated greywater

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**Abstract:** Water scarcity is a major problem in developing countries especially in the Middle East and African countries, thus necessitating domestic water recycling. A portable 3-layer, transparent domestic greywater treatment was designed and constructed for this study. Wastewater was collected from Boluid cafeteria located in Nnamdi Azikwe Hall, University of Ibadan, Nigeria and pre-filtered using 1.00 mm sieve before being stored in a cooler. Kenaf fibre and core were obtained from the Institute of Agriculture and Research Training (I.A.R.&T) Moor plantation, Ibadan, Nigeria. The kenaf fibre was hand woven into a mat and placed within the treatment unit while the kenaf stems were further milled using a plate mill and packaged in a water permeable medium. The parameters (dissolved oxygen (DO), total suspended solids (TSS), total dissolved solids (TDS), pH, Electrical conductivity and temperature) of the influent as well as the effluent were measured to determine the effect of treatment on the greywater. No significant changes were recorded for pH and temperature. DO reduced by 13.03% and 9.67% for core and fibre treatment respectively, TDS by 13.25% and 12.71% for fibre and core correspondingly. Suspended Solids recorded a percentage reduction of 26.93% and 18.08% for both core and fibre strained effluents, the electrical conductivity reduced by 5.01% and 5.38% for core and fibre percolated layers while the turbidity decreased by 37.36% and 42.82% for both core and fibre filtered greywater. Changes in parameters signifies the treatment had occurred, the pH, temperature, TDS as well as electrical conductivity of the effluents were within the acceptable limits specified for reuse whereas the turbidity, TSS as well as DO signify extra measures needed to be taken.

**Keywords:** domestic greywater, Kenaf core and Fibre, filtration treatment, parameters.

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## 1 Introduction

Water connects every aspect of life. Its adequacy is important for a wide range of domestic, industrial, agricultural, social and economic functions. Thus, the availability of safe water can adversely turn problems into potential. Thereby, creating more educational opportunities, work opportunities, and improved health for women, children and families across the world. However, meeting the adequate domestic water requirement in rural areas has always been a daunting

task, especially during dry seasons when the water table level has gone down and rainfall is limited. Access to treated water is so important that it is the sixth global goal for sustainable development, SDG6 (UNDP, 2015).

Domestic water can be classified into three: whitewater, greywater and blackwater. Whitewater is potable water used for cooking, bathing, consumption, laundry etc. Greywater is whitewater used for domestic purposes usually containing oil, soap, food particles and other impurities while blackwater is

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wastewater containing faecal, blood and urine waste (Al-Gheethi et al., 2019). Of the two wastewaters, greywater is produced domestically in larger volumes and it has higher quality than blackwater.

This research is centred on reducing the effects of water scarcity in drought-prone regions during dry season by recycling domestically generated greywater through good 'housekeeping practices' (Sangodoyin, 2011). This implies that treated greywater should be reused for a similar purpose until it is deemed non-usable and subsequently discarded. The concept of wastewater reuse has received increased attention recently due to the increasing cost of potable water, degradation of freshwater resources resulting from improper disposal of waste and wastewater into water bodies, and prediction of further droughts from climate change in many arid areas (Adewumi and Oguntuase, 2016). The primary objective of this research is to develop an easy-to-operate, effective and affordable greywater treatment for domestic purposes, the effluent of which can be utilized as an alternative to potable water for certain domestic activities such as cleaning of the surroundings as well as irrigation, thereby conserving potable water for more pressing needs. This approach also reduces the cost of municipal water supply while ensuring adequate use of water for various uses for various household purposes, especially in the arid regions (Threlfall, 2000; WHO, 2006; Ilemobade et al., 2009).

There are quite a number of methods for treating greywater, some of which include filtration, coagulation and sedimentation, reverse osmosis, neutralization, aeration, precipitation, anaerobic digestion and aerobic digestion, tertiary treatment (specific treatment) as well as disinfection. In practice, some greywater treatment involves two or more of these treatments (Yongabi et al., 2011). The domestic greywater treatment is designed to be economical and will be filtration based using agricultural materials. These methods also apply to treatment of ground and rain water, and are used to provide potable water for municipalities and are quite expensive to establish (Khow et al., 2000). There are also expensive individual

portable filters for travellers and hikers that combine filtration with chemically altered plant materials. These materials have to be replaced after each use.

The need to make the treatment system as affordable as possible has necessitated the use of agricultural materials, industrial by-products, naturally occurring rocks and minerals such as *Commelina* sps., *Polygonum* sps., and *Typha* sps., oil palm fibre, cotton, coconut fibre, pine tree wood, rice husks, orange peels, groundnut shell, chitosan, lignin, fly ash, wood sawdust, fish scales, and jute fibre (Wan Ngah and Hanafiah, 2008; Patale et al., 2010; Katukiza et al., 2014; Rahman and Islam, 2020; Ibrahim et al., 2022). The use of agricultural materials as a cheap filtration medium rose from the fact that agricultural materials are more naturally available and easier to modify when compared to naturally occurring mineral rocks such as fine sand, gravels, zeolites, calcites, dolomites, pumices etc. which are region-specific and denser. Agricultural materials are also ecologically friendly, are widely available and the spent agricultural-based filter can be used as either fuel or compost.

The development of a domestic greywater treatment system using agricultural material as a filtration medium would aid rural communities conserve greywater for later utilization. This would reduce the demand of potable water and subsequently the stress associated with getting potable water. The filtration medium for the treatment system is sourced from the stem of the *Hibiscus cannabinus* L. (Kenaf) plant, belonging to the *Malvaceae* and similar to cotton, okra, and hollyhocks and growing in the wild in Eastern African region (Wilson, 1978; LeMahieu et al., 1991). Kenaf as a multifunctional crop is grown for cordage, human feed, animal consumption and oil absorption, is majorly grown in southern Nigeria during the dry season and in the Northern Nigeria during rainy season as it requires minimal rainfall with the Southern part accounting for about 60% of national production with an estimated tonnage of 1460 ton year<sup>-1</sup> ranking 4<sup>th</sup> and 13<sup>th</sup> continentally and globally respectively Varieties like Ifeken 400, Ifeken D1 400, Artken, Ifeken 100 and Girin danani are developed

locally while exotic varieties such as Cuban 108, Tainnung 1, Everglades 71 and 41, Salvador and Guatemala 2A (51) are also available (Odumuyiwa et al., 2024; Adetumbi et al, 2022; Anonymous, 2022; Habibu, 2020).

The plant-based filtration method would be used to assess changes in parameters associated with testing wastewater, which encompasses pH, turbidity, total dissolved solids (TDS), dissolved oxygen (DO), temperature, electrical conductivity, total suspended solids (TSS), and odour amongst others (Patale et al., 2010; Gross et al., 2015; Oteng-Peprah et al., 2018; Al-Gheethi et al., 2019).

## 2 Materials and methods

### 2.1 Design

According to Boyjoo et al. (2013), greywater generation for residential regions in Africa and Middle East ranges 14-161 Litres per person per day. Thus, maximum value is considered.

The treatment system can be operated during active hours, considering rest period of 12 hours, thus requiring an operational period of 12 hours.

There is also an assumed number of runs per hour, 3 times per hour.

According to Uzomba (2019), the treatment capacity is derived from the Equation (1).

$$V = \frac{Q}{n \times H} \quad (1)$$

Where,

Q = Quantity of wastewater to be treated (L person<sup>-1</sup> Day<sup>-1</sup>);

n = Number of runs per hour;

H = Actual working period (hrs Day<sup>-1</sup>);

V = 4.472 L per run.

Capacity of treatment system is obtained by multiplying Equation 1 by a designated factor of safety to give Equation 2 (Kadiri, 2023).

A factor of safety *F*, of 2.5 is also considered for this design.

$$C = F \times V \quad (2)$$

C = 11.18 L

For the purpose of easy fabrication, a 12.5 L

capacity chamber was chosen. The dimension will be 50 cm × 20 cm × 12.5 cm as shown is Figure 1. Handwoven mats from kenaf fibres and packaged milled dried kenaf stems would be used as filtration medium. The treatment chamber is a three-layered transparent filtration system equipped with a sprinkler head to enable effective dispersion across the surface portrayed in Figure 2.

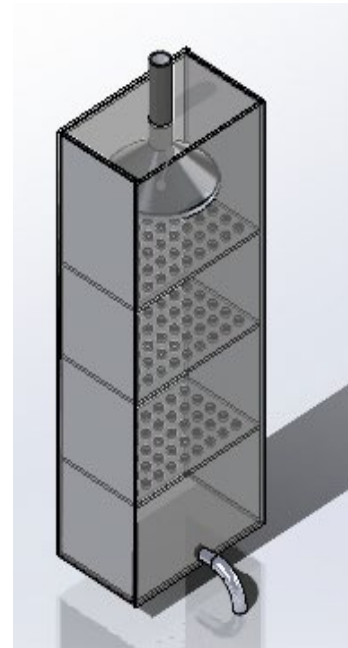


Figure 1 Engineering drawing of the treatment System



Figure 2 The treatment unit

### 2.2 Materials

The materials used for the construction of the domestic greywater treatment system are tabulated in Table 1.

**Table 1 Materials used for constructing the treatment system**

Materials	Quantity and Uses
PVC pipes	PVC pipes of 5 mm diameter and 50 mm length for the inlet
Sample bottles and beakers	20 cm <sup>3</sup> and 25 cm <sup>3</sup> volume
Transparent plastic	For the fabrication of the setup 2 m x 4 m
Sieve	1mm sieve to filter the wastewater before it is initiated to the setup
Sprinkler head	To spray the wastewater evenly over the Kenaf material in the filtration setup at the inlet
Tap	Fitted at the base of the treatment setup to aid the collection of the treated water
Glue	Used for joining the various cut out parts of the transparent plastic material used to construct the setup

### 2.3 Methodology

Wastewater was collected from Boluid cafeteria located in Nnamdi Azikwe Hall, University of Ibadan, Nigeria. It was then passed through 1.00 mm sieve before being stored in a cooler. Six (6) number of 10,000 cm<sup>3</sup> sieved cafeteria wastewater was used for the tests. Three (3) samples each for knitted fibre and milled stem, the average values of the results of the wastewater treatment were recorded. Kenaf fibre and

core were obtained from the Institute of Agriculture and Research Training (I.A.R. & T), Moor Plantation, Ibadan, Nigeria.

The Kenaf fibre was hand woven into mats as shown in Figure 4 and placed within treatment unit while the kenaf stem were further milled using a plate mill and packaged in water permeable medium as depicted in Figure 3.



Figure 3 Packaged milled kenaf core and pith

The parameters of the influent as well as the effluent were measured to determine the effect of treatment on the greywater.

#### 2.3.1 Temperature

The temperature of both influent and effluent were recorded using Celsius calibrated mercury in glass thermometer.

#### 2.3.2 pH

The pH of influent and effluent for both Kenaf fibre and stem were obtained using HANNA #151-R pH meter. The pH meter was calibrated before each



Figure 4 Hand woven kenaf mats

test using a standard buffer 7.0 solution.

#### 2.3.3 Dissolved oxygen (DO)

The dissolved oxygen content of the samples was determined using an EDT RE 347 Tx DO meter.

#### 2.3.4 Total dissolved solids (TDS) and electrical conductivity

Both parameters of the samples were determined using JENWAY 4510 conductivity meter.

#### 2.3.5 Turbidity

The turbidity of the samples was measured using a HACH DR/2000 Turbidimeter, and the

turbidimeter was calibrated using 25mL of deionized water before each sample testing.

TSS =

$$\frac{(\text{Mass of Dried filter paper + Solids}) - \text{Mass of empty filter paper}}{\text{Volume of Sample}} \times 1000000 \left(\frac{mg}{l}\right) \quad (3)$$

### 2.3.6 Total suspended solids (TSS)

The TSS of the samples was determined by measuring the mass of dried solid removed from

samples after it has passed through a pre-weighed filter paper. TSS is mathematically obtained from the mathematical Equation 3 (AOAC, 2012).

## 3 Results and discussion

Table 2 shows the properties of the influent and effluent of the domestic wastewater treatment system when both core and fibre were used separately as filtration media. These values were compared to WHO and NESREA standards depicted in Table 3.

**Table 2 Effect of treatment on the properties of the greywater**

Parameter	Initial value	Core treatment	Fibre treatment	% Removal (Core)	% Removal (Fibre)
pH	7.462	7.458	7.464	-	-
Temperature (°C)	30.5	30.44	30.64	-	-
DO (mg L <sup>-1</sup> )	1.1112	0.9664	1.0038	13.0310	9.6652
TDS (mg L <sup>-1</sup> )	1114	972.4	966.4	12.7110	13.2496
TSS (mg L <sup>-1</sup> )	212.4	155.2	174	26.9303	18.0791
Electrical Conductivity (µs)	166.8	158.44	157.82	5.0120	5.3837
Turbidity (NTU)	34.8	21.8	19.9	37.3563	42.8161

**Table 3 Wastewater effluent quality criteria (WHO & NESREA Standard)**

Parameter	WHO standard	NESREA standard
pH	6.5-8.5	6.0-9.0
Temperature (°C)	40	40
DO (mg L-1)	5.0-10.0	4.0
TDS (mg L-1)	1000	1000
TSS (mg L-1)	30	35
Electrical Conductivity (µs)	400	-
Turbidity (NTU)	10	10

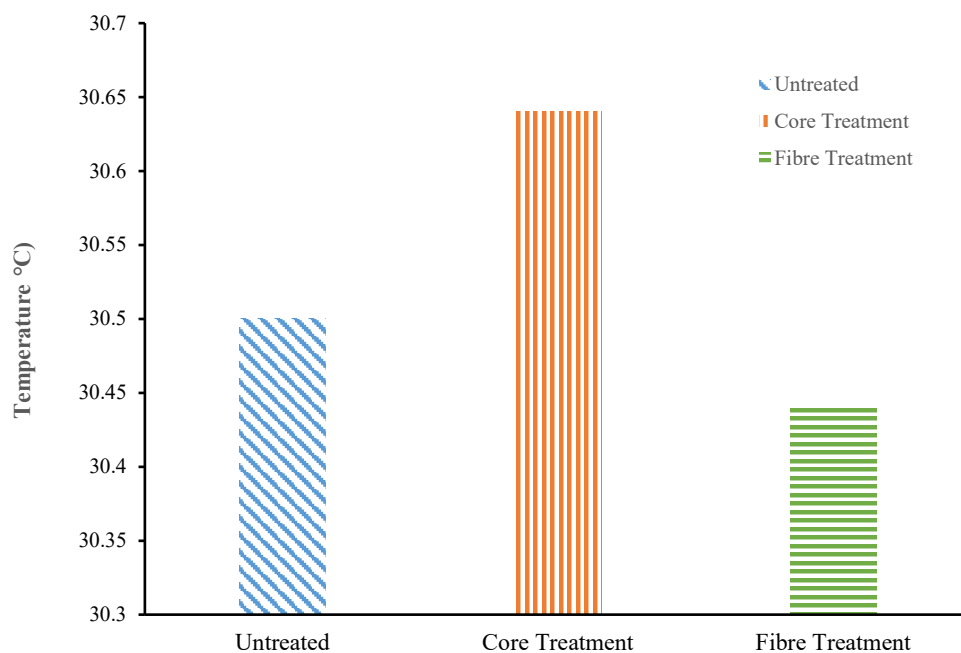


Figure 5 Effect of treatment on temperature influents and effluents

The temperature of the influent also had a negligible change when treated with Kenaf core and fibre filtered greywater respectively as portrayed in Figure 5. These values are also within the acceptable limits for both NESREA and WHO standards, thus not requiring thermal treatment. From Table 2 and Figure

6, It is observed that there were no significant changes in the pH of both effluent and influent for the core and fibre treated greywater with pH values of the effluents. These values were within the tolerable range for both WHO and NESREA standards, signifying no need for further neutralization treatment.

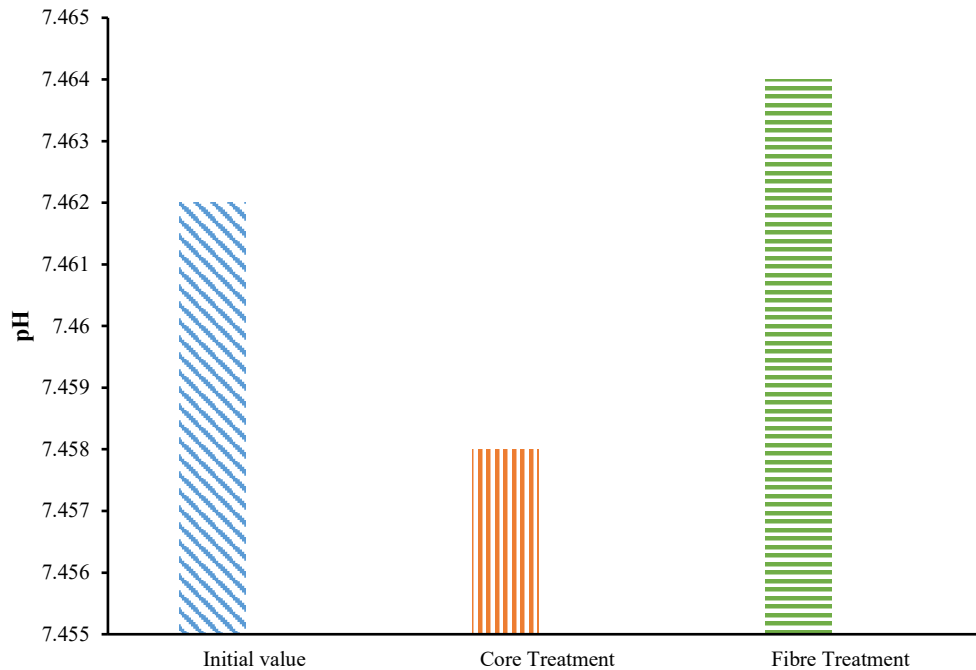


Figure 6 pH Analysis of influents and effluents

According to Figure 7, there was a reduction in the dissolved oxygen (DO) values of the effluent. These values were observed to be less than the standard values stipulated by NESREA and WHO. This can be rectified by aerating the wastewater preceding or during filtration.

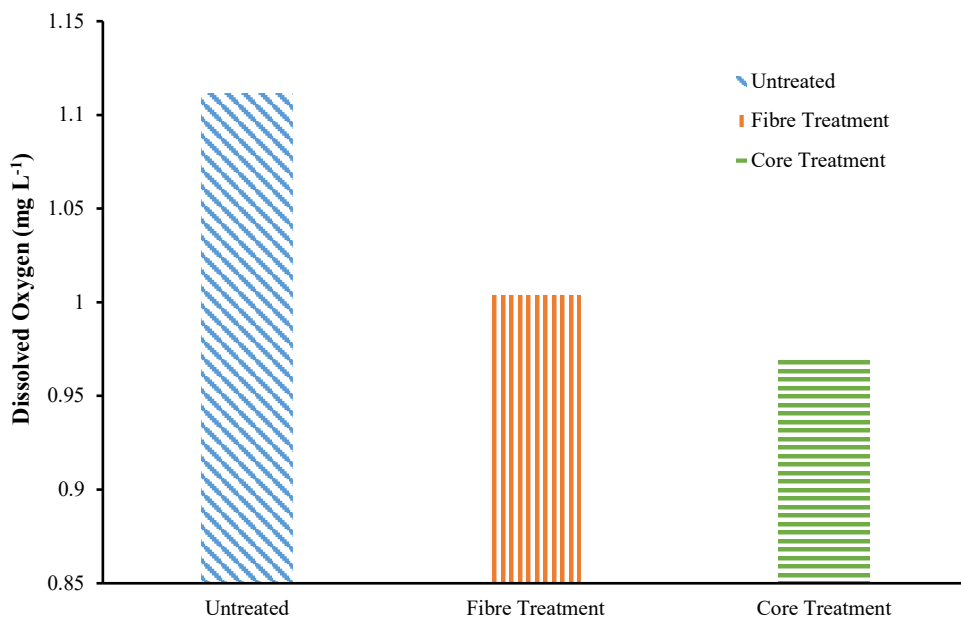


Figure 7 Effects of treatment on DO

The values of Total dissolved solids (TDS) were also compared and presented in Figure 8. The Total

Dissolved Solids content of the influent was also slightly reduced by the treatment system for both fibre

and stem and were lower than the stipulated WHO and NESREA standards for effluents, thus implying no other treatment is required in this regard.

As portrayed in Figure 9, the electrical

conductivity of the influent also slightly decreased for both core and fibre percolated layers. These were also lower than the postulated WHO standard, therefore, no further treatment is required.

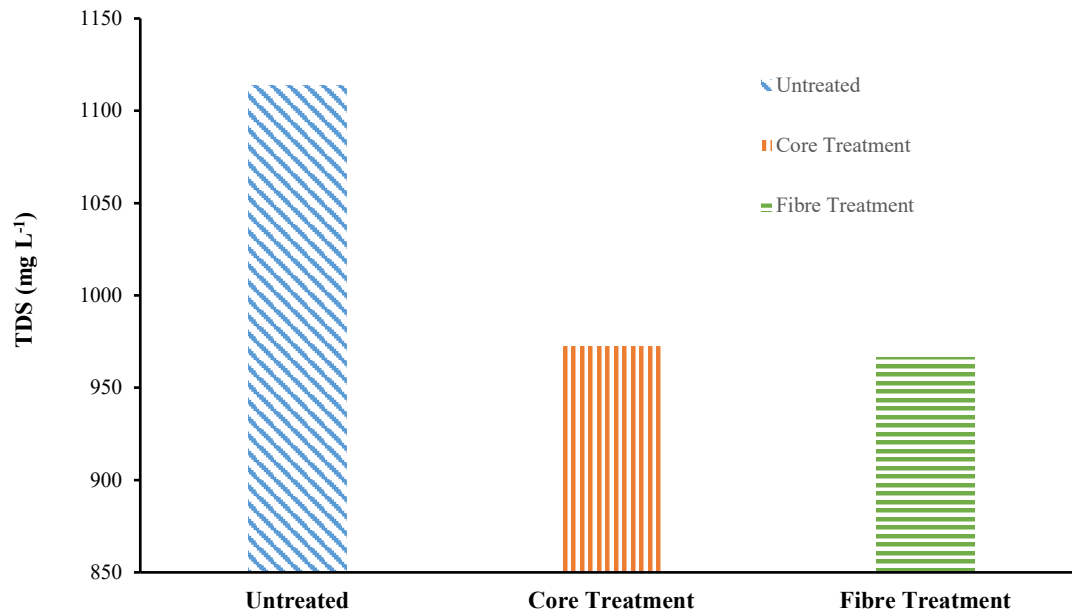


Figure 8 Effects of treatment on total dissolved solids (TDS)

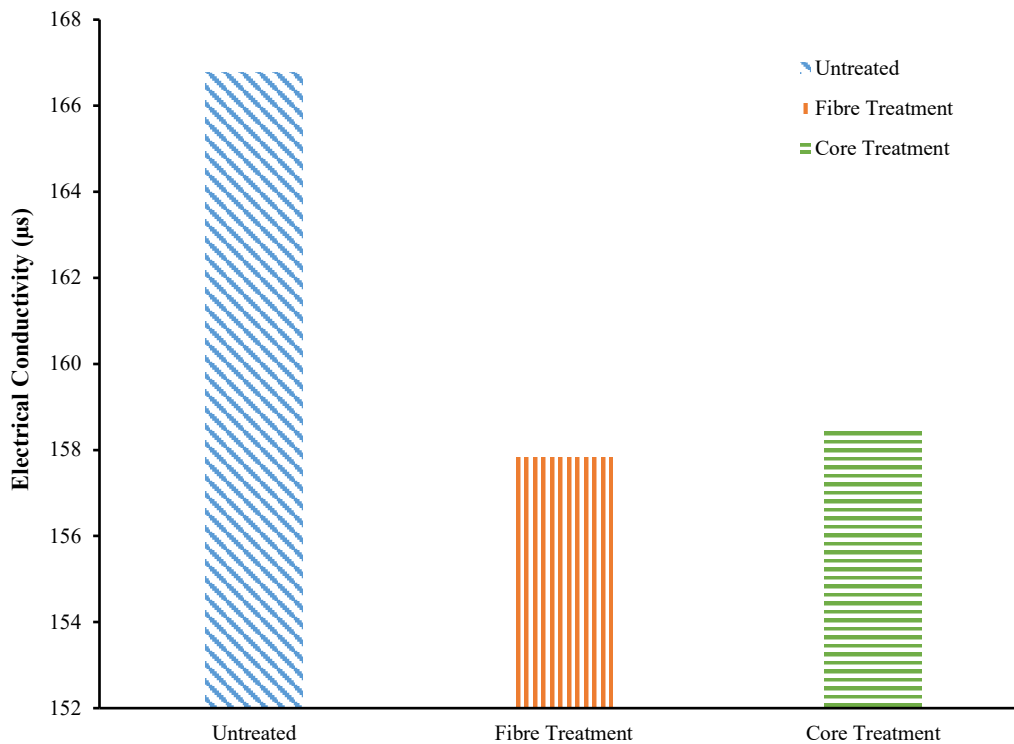


Figure 9 Effects of treatment on electrical conductivity

According to Figure 10, there was a reduction in the total amount of suspended solids (TSS) values of the influents although, the TSS values of the effluents were observed to be 5-6 times higher than the standard

figures required by NESREA and WHO standards. This signifies that the use of coagulants as pre-treatment is necessary to improve the quality of effluent.

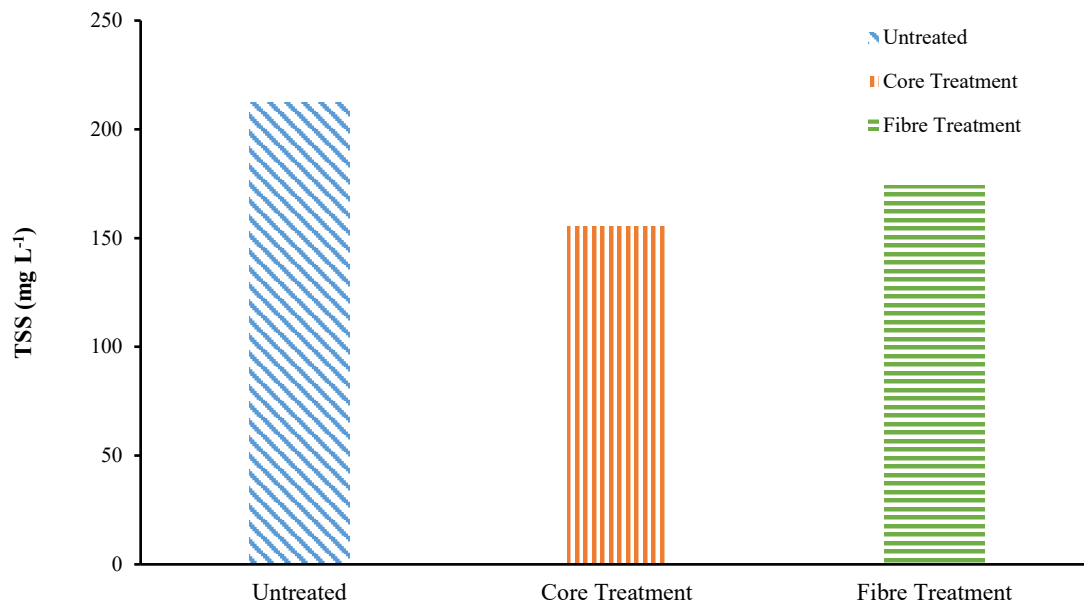


Figure 10 Effect of treatment on total suspended solids (TSS)

Figure 11 depicts the effect of treatment on the turbidity of the greywater. Although there was a significant reduction in the turbidity of the wastewater, the effluent’s turbidity was still significantly higher

than the specified turbidity of 10 NTU reported for WHO and NESREA standards, thereby necessitating the need for coagulants and flocculation before filtration.

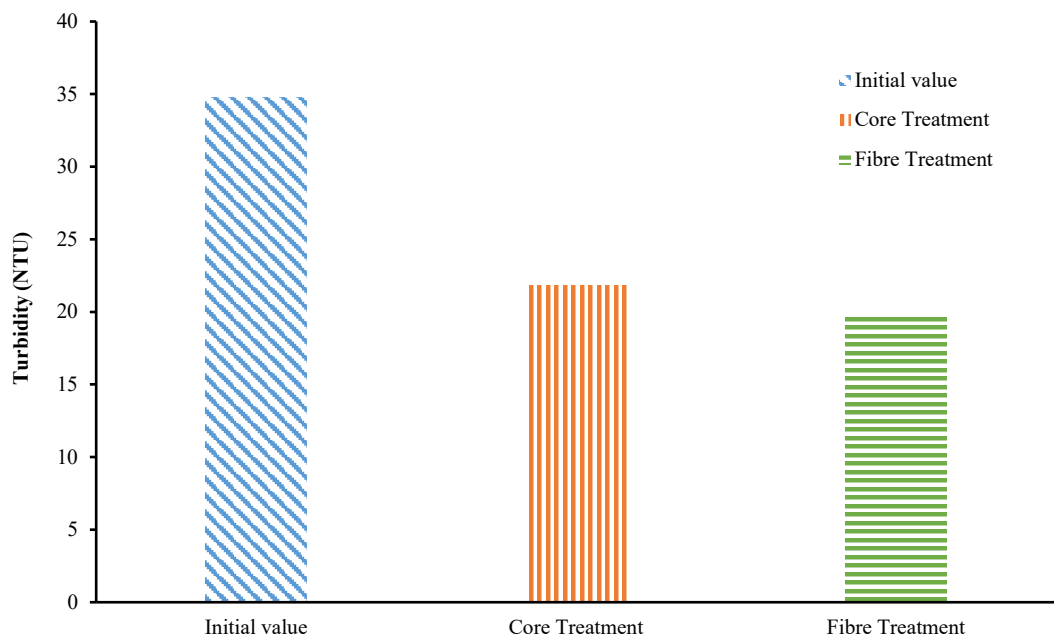


Figure 11 Effect of treatment on turbidity

## 4 Conclusion and recommendations

### 4.1 Conclusion

The effluent was discovered to have better qualities than the influent, this indicated that some degree of treatment has occurred. The pH, temperature, TDS, and electrical conductivity were within the acceptable range. The turbidity as well as TSS values were still

higher than the required standard for reuse. This can be rectified through the use of coagulants coupled with flocculation. This will result in larger particle aggregates that can sink or be easily filtered out by the kenaf layers.

The DO value of the effluent was also discovered to be far below the required value for greywater reuse measuring at about 20% of the standard. This situation

can be remedied by the use of aerator or by flocculation in a highly aerated container.

The low value of Electrical conductivity when compared to WHO standards is an indication of low contents of ionic chemicals mostly in the form of salts thus implying that there will be no need for any form of equalization or chemical treatment.

#### 4.2 Recommendations

The use of coagulants and flocculation is highly recommended as a pre-treatment as it should help in improving the efficiency of treatment. Commercially available and affordable coagulants including agricultural materials like ground moringa seeds, guar gum and jatropha should be used to reduce the financial stress on residents in developing countries (Abatneh et al., 2014). Flocculation is also recommended alongside coagulation to boost the aggregation of the tiny colloidal components of the greywater influent.

Also, for obtaining more accurate results, the Kenaf core and fibres can be used at the same time in the treatment unit to obtain even purer water. Since it has been observed that the cores are more effective in treating specific parameters than the fibres such as DO and suspended solids while the fibres are more effective in treating other parameters such as turbidity, electrical conductivity and dissolved solids; a simultaneous use of both materials should produce a more complete result and increase reusability of the wastewater after treatment.

Agricultural materials are vast and available based on locality, plants and by-products can be used in making filtration media as presented in Rahman and Islam (2020). The plant materials filter medium can be used alongside rocks and sand filter medium. This would likely enhance water purification.

Plant based personal water filters are being produced and sold, the principles used to make them can be developed industrially and commercially to remediate chemically polluted water bodies in rural regions.

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