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PERFORMANCE ASSESSMENT OF SUGARCANE BAGASSE AS FILTER MEDIA FOR GROUNDWATER TREATMENT IN BIDA METROPOLIS

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Abstract

Groundwater serves as the primary source of domestic water supply where access to save drinking water remains a major challenge. However, groundwater quality is often compromised by suspended solids, dissolved contaminants, and microbial pollution. This study investigates the effectiveness of sugarcane bagasse as a filtration medium for groundwater treatment in Bida, Niger State, Nigeria. Sugarcane bagasse obtained from local sugarcane vendors was washed, dried, and was thereafter processed to Activated carbon (AC) using the chemical activation process where it was carbonized at a temperature of 480 ^{o}C for two hours, before being used as filter media in a laboratory-scale filtration column. The produced activated carbon was divided into two different particle sizes; Powdered activated carbon (PAC) and Granular activated carbon (GAC). Groundwater sample collected from Dokota within Bida metropolis was analyzed before and after filtration. Key water quality parameters including turbidity, pH, total dissolved solids (TDS), electrical conductivity, and total coliform bacteria were determined using standard analytical methods. The results showed significant improvements in water quality after filtration through the bagasse filter column. It was observed that, PAC (powdered activated carbon) was more suitable for groundwater filtration than the granulated activated carbon (GAC) as it showed a higher removal efficiency of the parameters after filtration. Turbidity decreased from an average value of 1.412mg/L to 0.389mg/L, representing approximately 75% removal

Keywords:
Sugarcane bagasse, Groundwater, Treatment, Filtration column, Activated carbon

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efficiency. Total dissolved solids reduced from 540mg/L to 470mg/L and electrical conductivity was also reduced, indicating adsorption of dissolved ions by the lignocellulosic structure of the bagasse. Microbial analysis revealed a substantial reduction in total coliform count from 100 CFU/100 ml to 27 CFU/100 ml after filtration. Fluoride (1.20mg/L), Calcium (170 mg/L), Arsenic (not detected), Iron (0.589 mg/L). These results are within drinking water standard stipulated by World Health Organization except for iron and total coliform count that was above maximum standard. The findings demonstrate that sugarcane bagasse possesses promising filtration and adsorption properties, making it a suitable low-cost material for preliminary groundwater treatment in rural communities. The study recommends further optimization and integration of bagasse filtration systems with disinfection processes for improved drinking water safety.

Introduction

Groundwater represents one of the most important sources of potable water worldwide, particularly in developing countries where centralized water treatment infrastructure is often inadequate. In many Nigerian communities, including Bida in Niger State, groundwater obtained from wells and boreholes serves as the primary source of domestic water supply. However, groundwater quality can be compromised by contaminants such as suspended solids, dissolved minerals, heavy metals, microorganisms, and organic pollutants. These contaminants may originate from agricultural runoff, industrial activities, landfill leachates, and natural geological processes (Gavrilescu, *et al.,* 2015). Water plays a significant role in maintaining the human health and welfare. Clean drinking water is now recognized as a fundamental right of human beings. Around 780million people do not have access to clean and safe water and around 2.5 billion people do not have proper sanitation. As a result, around 6–8 million people die each year due to water related diseases and disasters (United Nation- Water, 2013). Groundwater contamination remains a major environmental and public health concern, especially in developing countries where access to advanced water treatment systems is limited. Conventional water treatment technologies such as membrane filtration, chemical coagulation, and ion exchange are effective but often expensive and technologically demanding for rural communities (Abu-Elhamid *et al*., 2024). Consequently, research efforts have increasingly focused on the development of low-cost, environmentally friendly materials for water purification. Agricultural wastes have attracted considerable attention due to their abundance, biodegradability, and adsorption capabilities (Elshabrawy *et al.,* 2023). Many studies have shown that

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agricultural by-products can serve as effective adsorbents for the removal of contaminants from water systems. Consequently, the use of low-cost adsorbents derived from agricultural wastes has gained significant research attention. Sugarcane bagasse, a fibrous by-product of the sugar industry, has been widely investigated for its adsorption and filtration properties due to its high cellulose, hemicellulose, and lignin content. These components provide numerous active sites that enhance pollutant adsorption in water treatment processes (Adegoke *et al.*, 2024). Recent studies have demonstrated that sugarcane bagasse can effectively remove contaminants such as dyes, heavy metals, and organic pollutants from water through adsorption mechanisms. Modified or treated bagasse materials have shown improved efficiency due to increased surface area and functional groups responsible for pollutant binding (Abd-Elhamid *et al.*, 2024). Sugarcane bagasse is the fibrous residue remaining after the extraction of juice from sugarcane during sugar production. It is produced in large quantities in sugar-producing countries and is often considered an agricultural waste product. The material is primarily composed of cellulose, hemicellulose, and lignin, which together form a complex lignocellulosic structure with significant adsorption potential (Langat *et al.*, 2024). Recent studies have demonstrated that sugarcane bagasse possesses a porous structure and high surface area that make it suitable for adsorption and filtration processes in water treatment applications. The presence of functional groups such as hydroxyl, carboxyl, and phenolic groups enables the material to bind with various pollutants through mechanisms such as adsorption, ion exchange, and surface complexation. As a result, sugarcane bagasse has gained increasing attention as a sustainable and low-cost bio-sorbent for water purification systems (Mubarak *et al.*, 2024). In addition to its adsorption properties, sugarcane bagasse is widely available and renewable, making it an attractive alternative to expensive commercial adsorbents such as activated carbon. The use of bagasse for environmental remediation also helps reduce waste disposal problems associated with sugar industries. The adsorption capacity of sugarcane bagasse has been widely studied for the removal of various contaminants from water, including heavy metals, dyes, oils, and organic pollutants. Adsorption is considered one of the most efficient and economical techniques for water purification due to its simplicity and effectiveness. Research has shown that sugarcane bagasse can effectively remove heavy metals such as lead and nickel from contaminated water. Experimental investigations revealed removal efficiencies exceeding 80–90% under optimized conditions, demonstrating the strong adsorption potential of the material (Ezeonuegbu *et al*., 2021). Adsorption via activated carbon from local agricultural wastes such as chitosan (Tham *et al*., 2013); rice husk (Nekoo & Shohreh, 2013), and also has removed 70 % to 99 % of O&G in car wash wastewater with limited researches on COD and MBAS removal. Previous studies on sugarcane bagasse or Saccharum officinarum towards industrial wastewater have

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successfully removed 46 % to 84 % of COD (Nekoo & Shohreh, 2013; Azmi *et al*., 2014; Gaikwad & Mane, 2015), 80 % of O&G (Sarkheil & Tavakoli, 2015) and 77 % to 95 % of MBAS (Co *et al*., 2012; Bilal *et al.,* 2013). It has 50 % cellulose, 27 % polyoses, and 23 % lignin with hydroxyl, carbonyl, aromatic group and other composition of polymers responsible for an excellent adsorbent capacity (Machado *et al*., 2025). The adsorption process in these studies was influenced by factors such as pH, contact time, temperature, and adsorbent dosage. Similarly, modified forms of sugarcane bagasse have been successfully applied for the removal of iron from aqueous solutions. Chemical treatments using agents such as sodium hydroxide and citric acid significantly enhance the adsorption capacity of bagasse by increasing its surface area and creating additional active sites for pollutant binding. Experimental studies have reported improved adsorption performance and reusability of treated bagasse materials for water purification applications (Thom & Thom, 2024). In addition to heavy metals, sugarcane bagasse has also been used to remove organic contaminants such as dyes from wastewater. Textile effluents often contain toxic dyes that are resistant to biodegradation and pose serious environmental hazards. Studies have shown that sugarcane bagasse pulp can effectively remove dye molecules from wastewater through adsorption mechanisms, making it a promising material for wastewater treatment processes (Elshabrawy *et al*., 2023). Although raw sugarcane bagasse exhibits good adsorption properties, several studies have demonstrated that its performance can be significantly improved through physical and chemical modifications. These modifications include acid treatment, alkali treatment, carbonization, and activation processes. One common approach is the production of biochar or activated carbon from sugarcane bagasse through thermal processes such as pyrolysis. Activated carbon is characterized as a carbonaceous material with a highly porous internal structure, which is usually derived from the pyrolysis and chemical treatment of sources including wood, coal, nutshells, bamboo and other organic materials (Gavrilescu *et al.,* 2015). The activation process, usually performed at high temperature by chemical or steam treatment, generates an extensive porous network within the carbonaceous material. The resulting materials exhibit enhanced surface area, improved pore structure, and increased adsorption capacity for various pollutants. Modified bagasse adsorbents have shown promising results in removing organic contaminants, heavy metals, and oils from water systems. Recent studies have also explored the synthesis of advanced adsorbent materials from sugarcane bagasse waste. For instance, researchers have developed zeolite-like materials derived from bagasse ash that demonstrate high efficiency in removing dyes and other industrial pollutants from aqueous solutions. Such innovations highlight the potential of bagasse-derived materials for sustainable water treatment technologies (Santana *et al*., 2026). Furthermore, optimization techniques such as response surface methodology have been applied to evaluate the adsorption

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performance of sugarcane bagasse in removing oil pollutants from water. These studies reported significant pollutant removal efficiency under optimized operating conditions, confirming the suitability of bagasse-based adsorbents for environmental remediation (Machado et al., 2025). The increasing interest in sustainable water treatment technologies has further promoted the application of agricultural waste materials such as sugarcane bagasse. Researchers have emphasized the potential of bagasse not only as an adsorbent but also as a precursor for bio-coagulants and composite filtration materials. Recent reviews have highlighted the prospects of using sugarcane bagasse in water treatment systems due to its low cost, high adsorption capacity, and environmental compatibility. However, challenges such as adsorbent regeneration, mechanical stability, and large-scale application still require further investigation (Iwuozor et al., 2023). The use of bagasse-based filtration media is particularly relevant in rural and semi-urban communities where access to advanced water treatment facilities is limited. By utilizing locally available agricultural wastes, communities can develop affordable and sustainable water purification technologies that improve water quality and public health. Although numerous studies have demonstrated the potential of sugarcane bagasse for wastewater treatment and pollutant adsorption, limited research has focused on its application as a filtration medium for groundwater treatment in Nigerian communities such as Bida. Groundwater quality in such regions often varies due to geological and environmental factors, necessitating localized studies to evaluate the effectiveness of low-cost filtration materials under specific conditions. Therefore, this study aims to evaluate the effectiveness of sugarcane bagasse as a filter medium for improving groundwater quality in Bida metropolis. The study contributes to existing knowledge by investigating the filtration performance of locally sourced bagasse in removing selected water quality parameters and assessing its suitability for sustainable water treatment applications.

Study Area

This study was conducted in Bida, located in Niger State, Nigeria. The town lies within the Guinea savannah ecological zone and relies heavily on groundwater sources such as wells and boreholes for domestic water supply. Due to the increasing dependence on groundwater for drinking and household purposes, concerns about water quality and contamination have become significant. Groundwater sample used in this study was collected at Dokota within Bida metropolis.

Sample Collection

Groundwater samples was collected from randomly selected hand-dug wells located at Dokota in Bida, Niger State. Clean polyethylene containers were used for sample collection. Prior to sampling, the container was thoroughly washed with distilled water to

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avoid contamination. The groundwater sample was collected in the morning hours and transported immediately to the laboratory for analysis.

Collection and Preparation of Sugarcane Bagasse

Sugarcane bagasse used in this study was obtained from local sugarcane juice vendors within Bida metropolis. In this study, the activated carbon (AC) was produced using the chemical activation process. The collected bagasse was washed thoroughly with tap water followed by distilled water to remove dirt, sugar residues, and other impurities. The washed bagasse was then sun dried for 2 – 3 days to remove moisture. The dried material was further carbonized at the temperarure of 480 ˚C for two hours after which it was impregnated with 28 ml sulphuric acid for 10g activated carbon in the activation process. The main purpose of the activation process is to open the pore surface area of the activated carbon. The activated carbon (AC) wass divided into two different particle sizes; granular and powdered particle sizes using Tyler mesh of idfferent sizes to obtain fine and coarse aggregate. The size of the granular activated carbon sugar bagasse (GAC SB) are between 150 µm and 300 µm while the powdered activated carbon sugar bagasse (PAC SB) is less than150 µm. The prepared bagasse was stored in airtight containers until use.

Preparation of Filtration Column

A laboratory-scale filtration column was constructed using a transparent plastic column of 10 liters each with a height of approximately 50 cm and an internal diameter of 5 cm. The column was packed with prepared sugarcane bagasse to act as the filtration medium. A layer of gravel was placed at the bottom of the columns to support the filter media and ensure uniform flow of water through the column. The prepared bagasse materials, both the GAC SB and PAC SB was then packed above the gravel layer to form the filtration beds. Groundwater sample was passed through the columns under gravity flow conditions, and the filtered water was collected from the outlet for analysis. The water treatment process was for 60minutes. All filterare run at the same time. An effluent flow from filter for every 15mins of retention time was collected until retention time of 60 minutes.

Water Quality Analysis

The physicochemical and microbiological parameters of the groundwater sample was analysed before and after filtration using standard laboratory procedures. The pH of the water samples was measured using a calibrated digital pH meter. Electrical conductivity (EC), dissolved oxygen (DO) and total dissolved solid (TDS) were calculated by electrometric method. Salinity was determined using ion exchange electrode method (Atekwanaa *et al*. 2004). Calcium present was determined using EDTA method. Iron was determined using Hach method 8008 (Ferro Ver). Nitrate was determined using

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colorimetric method with HACH standards/methods 8039 high range (Jaiswal, 2003). Turbidity was determined using a turbidity meter. The spectrophotometric method was used for colour determination. Microbial analysis for total coliform bacteria was carried out using the membrane filtration method. All analyses were conducted in accordance with standard methods for water and wastewater examination.

Table 1: Physicochemical Parameters of Groundwater Before and After Filtration

Parameters	Before Filtration	After Filtration		WHO Standard
		GAC	PAC	
pH	6.3	6.8	6.9	6.5 – 8.5
Nitrate (mg/L)	8.23	14.92	10.68	10(N)
Fluoride (mg/L)	3.53	2.32	1.20	1.5
Calcium (mg/L)	250	220	170	200
Turbidity (mg/L)	1.412	0.643	0.389	5
Electrical conductivity (µS/cm)	800	767	760	1000
Total dissolved solids (mg/L)	540	463	470	500
Arsenic (mg/L)	0.273	-	-	0.1
Iron (gm/L)	1.023	0.840	0.589	0.3
Total Coliform (CFU/100ml)	100	30	27	0
Colour	35	23	14	15

Turbidity is an important indicator of water quality as it represents the presence of suspended particles in water. The initial turbidity of the groundwater sample was 1.412 mg/L, after filtration through the sugarcane bagasse column, turbidity was reduced to 0.643 and 0.389 mg/L for GAC and PAC, representing a removal efficiency of approximately 54.46% and 75% respectively. This reduction indicates that the fibrous and porous structure of bagasse effectively traps suspended particles and colloidal materials present in groundwater. The result agrees with previous studies that reported high turbidity removal efficiency using agricultural waste materials as filtration media.

Total dissolved solids represent the concentration of dissolved inorganic and organic substances present in water. High levels of TDS can affect the taste and overall quality of drinking water. It is observed from table 1 above that, the TDS concentration decreased from 540 mg/L to 463mg/L for GAC and 470mg/L for PAC after filtration. Although the reduction was moderate, it indicates that sugarcane bagasse possesses some adsorption capability for dissolved substances. The observed reduction may be attributed to the adsorption of ions onto the lignocellulosic components of bagasse such as cellulose and lignin. The results for Heavy metal in raw water are as follows: Nitrate (18.23 mg/L),

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Fluoride (13.53 mg/L), Calcium (230 mg/L), Arsenic (0.873 mg/L), Iron (1.023 mg/L) before filtration and reduced after treatment. Thus, water contains impurities and not edible for ingestion. Ingestion of heavy metals in raw water can cause hazard in the body. According to the World Health Organization, the maximum acceptable concentration of fluoride ions in drinking water lies below 1.5 mg/L. Depending on the concentrations and the duration of fluoride intake, it could have positive effect on dental caries (Mahramanlioglu, *et al*, 2002). On the contrary, long-term consumption of water containing excessive amounts of fluoride can lead to fluorosis of the teeth and bones (Jamodei *et al*, 2004). The excessive intake of fluoride may cause dental (Gonzales *et al*, 2004) [4] and skeletal disorders (Solangie, *et al,* 2009). Electrical conductivity reflects the presence of dissolved ions in water. The conductivity of the groundwater samples decreased from 800 µS/cm to 767 and 760 µS/cm for GAC and PAC after filtration. This reduction suggests that sugarcane bagasse has the ability to remove certain ionic species from groundwater through adsorption mechanisms. The conductivity values recorded after filtration fall within acceptable drinking water limits established by the drinking water standards. Microbial contamination remains one of the major concerns associated with groundwater quality in rural communities. The presence of coliform bacteria indicates possible contamination by pathogenic microorganisms. The results of microbial analysis showed that total coliform counts were reduced from 100 CFU/100 ml to 30 and 27 CFU/100 ml after filtration through sugarcane bagasse media. This reduction represents a removal efficiency of approximately 70% in GAC and 73% in PAC. The reduction in microbial load may be attributed to the physical filtration and adsorption properties of the bagasse material. However, the coliform count after filtration still exceeds the recommended drinking water limit of zero CFU/100 ml according to the World Health Organization, indicating that additional disinfection processes such as chlorination or boiling may still be required before consumption. Generally, it can be observed that, PAC (powdered activated carbon) has proven that it's the most suitable activated carbon product for groundwater treatment having the highest removal efficiency after filtration. The results are within drinking water standard stipulated by World Health Organizationon except for iron and coliform count that was above the stated standard. The results indicate significant improvements in water quality after filtration through sugarcane bagasse as filter media. The results were compared with the recommended drinking water quality standards provided by the World Health Organization and the Standard Organisation of Nigeria in order to evaluate the suitability of the treated groundwater for domestic use.

CONCLUSION

The study evaluated the effectiveness of sugarcane bagasse as a filtration medium for groundwater treatment in Bida. The results showed that powdered sugarcane bagasse

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activated carbon (PAC SB) was more effective in treating the groundwater than the granulated sugarcane bagasse activated carbon (GAC SB). Significant reductions in turbidity, heavy metals, microbial load, electrical conductivity, and total dissolved solids after filtration was observed. Turbidity removal efficiency reached approximately 75%, while microbial reduction exceeded 70% using the PAC SB. The findings demonstrate that the smaller particles of activated carbon are more effective in the treatment process. The findings also demonstrate that sugarcane bagasse possesses promising filtration and adsorption properties, making it a suitable low-cost material for groundwater treatment in rural communities. However, additional disinfection methods may be required to ensure complete microbial safety of the treated water. The use of sugarcane bagasse as filter media also provides an environmentally sustainable approach for utilizing agricultural waste while improving water quality.

RECOMMENDATIONS

The following recommendations are made based on the research findings:

1. Statistical optimization of sugarcane bagasse for ground water treatment.
2. Further studies on long -term performance and regeneration of bagasse filters.
3. Treatment and Optimization of industrial waste effluent using treated bagasse.
4. Chemical modification of bagasse to improve adsorption capacity
5. Microbiological analysis and optimization of sugarcane bagasse for ground water treatment.

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