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HOUSEHOLD WASTE WATER TREATMENT WITH THE AID OF ACTIVATED CHARCOAL

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ABSTRACT

The efficiency of charcoal filtration in enhancing water quality parameters shows variability across multiple metrics. Using charcoal filtration resulted in a significant reduction in turbidity, with a 95.83% decrease. This suggests that charcoal filtration is highly effective at clarifying water by successfully eliminating suspended particles. Furthermore, it substantially reduced 77.68% in total dissolved solids (TDS), demonstrating its effective elimination of dissolved contaminants from the water. We made significant progress in reducing biological oxygen demand (BOD) by 55.71%, indicating successful degradation of organic contaminants. Charcoal filtration demonstrates its effectiveness in improving water clarity and lowering specific impurities, such as total dissolved solids (TDS) and turbidity. However, its effectiveness is subject to variation depending on different factors. This emphasizes the importance of implementing customized water treatment strategies based on specific quality standards and environmental factors.

Keywords: Activated charcoal, River, Test of water sample, Filtration, Water quality parameters.

Abbreviation

TDS	Total dissolved solids
BOD	Biological oxygen demand
WW	Wastewater
AC	Activated charcoal
$(Al_2(SO_4)_3)$	Aluminium sulphate
FP	Filter paper
CG	Chhattisgarh
mg/L	Milligrams per liter
ppm	Parts per million
NTU	Nephelometric turbidity units
WHO	World Health Organisation

INTRODUCTION

Efficient treatment of domestic wastewater is becoming more crucial to reducing environmental contamination and safeguarding public well-being (Djeddou and Achour, 2015; Gaouar and Gaouar, 2016; Obaideen et al., 2022; Aroua-Berkat and Aroua, 2022). Given the urbanization and population density increase, it has become critical to develop efficient techniques for treating wastewater from residential areas (Silva, 2023; Bhatnagar et al., 2013; Wise and Swaffield, 2012). Activated charcoal, also known as activated carbon, is a highly adaptable and successful instrument in wastewater treatment due to its outstanding capacity to adsorb substances and its wide range of applications (Ouakouak and Youcef, 2016; Gupta et al., 2016; Masmoudi et al., 2018; Jiang et al., 2019; Hassen and Abdulkadir, 2022). Activated charcoal is a porous substance with a large surface area per unit volume (Bouchemal and Achour, 2007; Khelili et al., 2010; Youcef et al., 2014; Kheliel et al., 2015; Alves et al., 2021). This allows it to effectively absorb and remove pollutants from water through physical and chemical processes (Zhang et al., 2018; Verma et al., 2024; Telgote and Patil, 2024). The adsorption method described involves attaching pollutants to the surface of activated charcoal particles, including organic molecules, chemicals, and some heavy metals. This attachment effectively eliminates these pollutants from the water (Ouakouak et al., 2010; Zhang et al., 2018; Kumar et al., 2019; Paustian et al., 1997; Wakawa et al., 2008).

Activated charcoal is essential for enhancing the quality of effluent released into the environment during home wastewater treatment (Bandosz, 2006; Fagrouch et al., 2012; Kesari et al., 2021). Household wastewater commonly contains a wide variety of pollutants, such as detergents, medicines, pesticides, and pathogens (Ounoki and Achour, 2014; Saleh et al., 2015; Gutiérrez et al., 2021). Conventional treatment procedures may not effectively eliminate all of these contaminants (Kumar et al., 2019). Activated charcoal efficiently tackles these issues by adsorbing a wide range of contaminants, hence improving the overall effectiveness of wastewater treatment procedures (Mekonnen et al., 2020; Tetteh et al., 2024). Activated charcoal's adaptability enables its integration into many treatment systems, including centralized treatment plants and decentralized units like septic tanks or greywater recycling systems (Kristanti et al., 2023). Various sizes of wastewater treatment systems, accommodating both urban and rural environments, can utilize its versatility (Kumar et al., 2019). Activated charcoal centralized systems frequently employ activated charcoal in filtration operations, sending wastewater through beds or columns containing activated charcoal particles. Impurities to the charcoal's surface result in a purer liquid waste that satisfies the necessary disposal standards (Zhang et al., 2018; Zaharia, 2017).

BACKGROUND OF THE STUDY

The study of treating household wastewater with activated charcoal has grown as more people become aware of the health and environmental problems that come from letting untreated or poorly treated wastewater from homes flow into the environment (Seow et al., 2016; Bai et al., 2023). In the past, residential wastewater has been a major cause of pollution. It contains a variety of harmful substances, including organic compounds, medicines, pesticides, and pathogens, which can negatively impact water quality and ecosystems (Kumar et al., 2019; Bacha and Achour, 2023). Activated charcoal, due to its extensive surface area and ability to adsorb substances, presents a hopeful alternative for addressing these problems (Abraham et al., 2018; Ahmed et al., 2022). Numerous industrial and municipal contexts have thoroughly examined and utilized the material's capacity to adsorb a diverse array of contaminants from water for many years (Zhang et al., 2018; Chauhan and Dikshit, 2023). The ability of this method to eliminate substances such as dissolved organic matter, bacteria, and trace pollutants makes it a desirable choice for enhancing the quality of domestic wastewater before its release into the environment (Aw et al., 2016; Mekonnen et al., 2020).

OBJECTIVE OF THE PRESENT STUDY

The objective of this study is to examine the potential application of charcoal as a filtration medium for water treatment.

1. To perform water sample filtration using charcoal as the filtering medium.
2. To assess the efficacy of charcoal as a filtration medium in water treatment.

MATERIAL AND METHODS

Activated charcoal

Activated carbon, sometimes known as activated charcoal (Musa et al., 2020; Baker et al., 2000; Derlet et al., 1986; Tetteh et al., 2024; Muttil et al., 2022; Ganjoo et al., 2023), is a type of carbon that is frequently employed to remove impurities from water and air, as well as for several other applications (Fig. 1). The substance undergoes a process of activation, resulting in the formation of small pores with a low volume (Saleem et al., 2021; Marsh and Reinoso, 2006; Heidarinejad et al., 2020). These pores significantly enhance the surface area, hence increasing the adsorption capacity. Typically, we obtain activated carbon from byproducts like coconut husks, and we have investigated the potential of paper mill waste as a source.

Figure 1: Activated charcoal

River bed sand

The sand extracted from river beds (Fig. 2), employed for water filtration, possesses a predominantly sub-rounded to rounded morphology. This specific shape makes it an ideal filtration medium for effectively capturing suspended solid particles in water. Sand filtration employs sand filtration to eliminate suspended matter and buoyant and sedimentary particles pass vertically through a dense layer of sand and gravel. Absorption or physical encapsulation eliminates the particles. However, the sand utilized for the experiment was obtained from the Seonath River bed in Durg, Chhattisgarh.

Figure 2: River bed sand

Gravel and pebbles

Gravel and pebbles (Fig. 3) play a crucial role in enhancing the quality of water in household wastewater treatment systems. They work alongside filtration techniques such as activated charcoal to improve water quality. Gravel is commonly utilized as a support material under activated charcoal beds to offer structural integrity and ensure the even distribution of wastewater. The porous quality of the material improves water flow, minimizing the chance of blockage and ensuring effective filtration. Pebbles, however, have dual use and serve both utilitarian and decorative purposes.

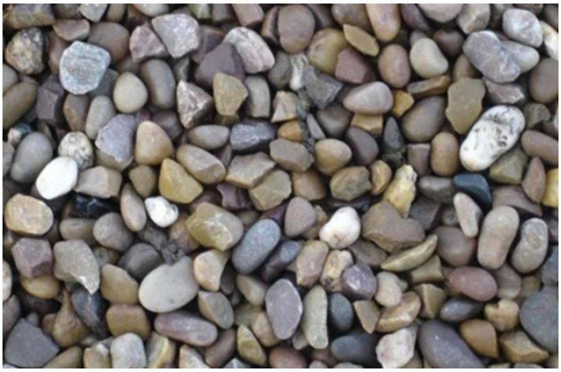

Figure 3: Gravel and pebbles (Ray et al., 2011)

Alum

Alum, also referred to as aluminium sulphate ($Al_2(SO_4)_3$), is a chemical substance that is frequently employed in water treatment techniques to clarify cloudy water. Turbidity is the state of being cloudy or hazy due to the presence of suspended particles in water, such as silt, clay, and organic matter. Alum uses coagulation and flocculation mechanisms to eliminate suspended particles (Fig. 4), improving water clarity and making it more suitable for a variety of applications.

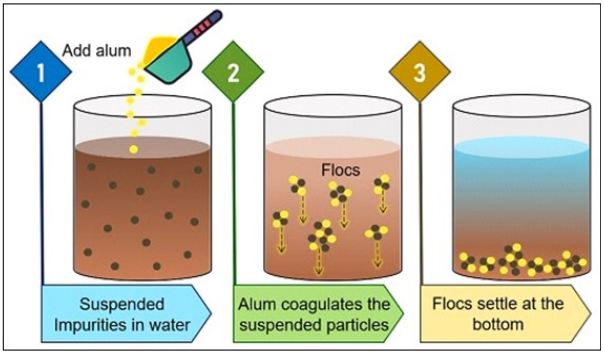

Figure 4: Purification of turbid water by utilizing alum.

Paper Filter

Filter paper (Fig. 5) is a permeable substance specifically created to filter particles from liquids or gases. Water purification frequently employs filter paper to eliminate particle matter and pollutants during filtration procedures. The small holes effectively capture suspended particles, silt, and even microbiological pollutants, resulting in water that is clearer and cleaner. Portable and residential water filtration systems commonly use filter paper to enhance the quality of water for drinking and other domestic purposes. It offers a straightforward and efficient approach to purifying water at different levels. However, The Newton Scientific firm in Supela Bhilai (CG) provides the filter papers used in the studies, which have a specific thickness and cost 75 rupees for a pack of 100.

Figure 5: Filter paper (https://www.westlab.com.au/).

METHODOLOGY

The process of treating residential wastewater using activated charcoal requires a series of essential processes to enable efficient filtration and purification of the wastewater. Here is a systematic approach to the methodology (Fig. 6).

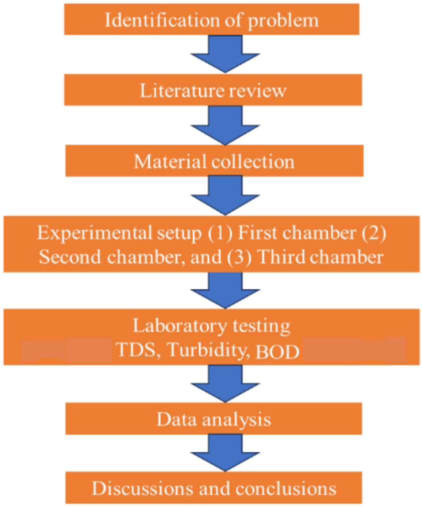

Figure 6: Methodology flowchart

EXPERIMENTAL SETUP

The household waste water filter is a compact and readily installable system that occupies minimal space in a house and requires a single, affordable expenditure. Additionally, the homeowner is not required to undergo routine inspections and maintenance of the system. The materials used in this system are readily available and derived from nature, thereby alleviating any additional strain on the homeowner. Fig. 7 illustrates the three distinct parts that define this system, which consists of numerous filtering systems.

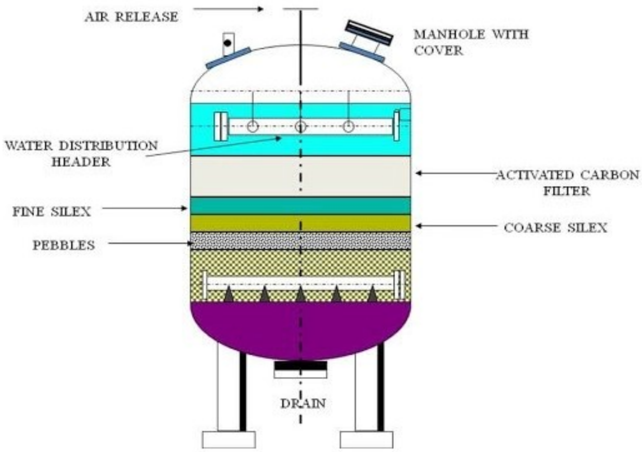

Figure 7: Design of household waste water filter with different chambers (https://www.filsonfilters.com/).

First chamber

The initial chamber, which serves as the main filtration unit, effectively eliminates large particles such as wood fragments, coarse granules, and hardened impurities, as well as partially removes oil and grease (Fig. 8). The composition consists of sand, together with coarse materials such as fragments of bricks, pebbles, and gravel, organized in distinct strata. The top layer consists of coarse solids, followed by gravel, sand, and pebbles in that order. The pebble layer acts as a protective barrier, preventing the water's movement through the system from eroding the sand. A conduit is available to transport water to the subsequent stage of purification.

Figure 8: Organized representation of the several levels throughout the initial chamber

Second chamber

The second chamber (Fig. 9), which is of utmost importance, is responsible for eliminating organic soluble compounds and is one of the most critical components found in household trash that can readily and significantly contaminate water. Household garbage contains a significant quantity of surfactants, which are chemical compounds. The chamber is mostly comparable to the one used in the first phase, except for the arrangement of layers and the inclusion of a highly influential natural element known as "activated charcoal." Activated charcoal forms the initial layer, followed by a layer of sand. A second layer of activated charcoal and a layer of pebbles follow.

Figure 9: Organized representation of the several levels throughout the second chamber

Third chamber

The first treatment step partially removes oil and grease, but it does not completely eradicate them. The amount of oil and grease discharged as waste varies from one household to another, depending on the resident's lifestyle and occupation. You can insert the optional third portion to eliminate the excess oil and grease. The design is quite basic. Water flows through an exit that follows the primary and secondary treatment chambers. This outlet contains a semi-permeable membrane that allows water to pass through while preventing the passage of oil. Instead of utilizing a semi-permeable membrane, we have the option to employ a sponge with small pores or filter paper. Coagulation and sedimentation occur in this segment. This context uses alum as the coagulant. In this area, water can remain stagnant for a significant duration (8–12 hours), allowing contaminants to accumulate. The following contaminants and pollutants have been listed alongside their respective removal percentages:

1. Total dissolved solids (TDS)
2. Biological Oxygen Demand (BOD)
3. Turbidity

Experiments Conducted

Determination of Total Dissolved Solids

Total Dissolved Solids (TDS) (Fig. 10) refers to the amount of inorganic and organic chemicals dissolved in water. Usually, we measure it in milligrams per liter (mg/L) or parts per million (ppm). Commonly, a conductivity meter or a TDS meter is used to ascertain the TDS (Suleiman and Abdullahi, 2011). In addition, measuring total dissolved solids (TDS) is crucial for evaluating the quality of water for a range of objectives, such as adhering to drinking water regulations, monitoring the environment, and facilitating industrial operations.

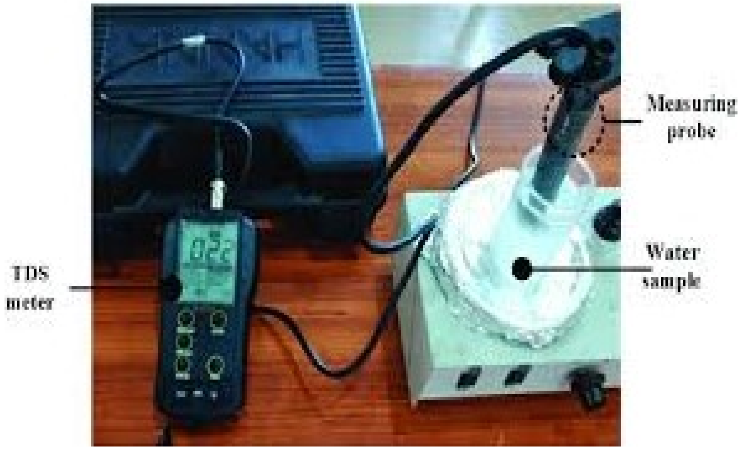

Figure 10: Total dissolved solids (TDS) meter

Determination of BOD

BOD, short for Biological Oxygen Demand, serves as a vital metric for assessing the extent of organic contamination in water. Microbes use Biological Oxygen Demand (BOD) to measure the amount of oxygen they use during the decomposition of organic substances, typically over five days. The process involves placing a water sample in a controlled environment without light and maintaining it at a specific temperature, often 20 °C. We measured the dissolved oxygen levels in the sample both before and after the incubation time to determine the amount of oxygen consumed. Potassium permanganate ($KMnO_4$) acts as the oxidizing agent in BOD analysis. It interacts with organic substances in the water sample to determine the amount of oxygen utilized (Udiba et al., 2018).

Determination of Turbidity

Turbidity determination is the process of quantifying the opaqueness or lack of clarity in a liquid due to the presence of suspended particles. The process commonly uses a nephelometer or turbidimeter (Fig. 11). Standards like formazin and silica can facilitate turbidity calibration. Sometimes, we use coagulants or flocculants to aid in the process of particle aggregation. However, ensuring regulatory compliance and monitoring water quality are just two examples of the many applications where accurate turbidity measurement is essential.

Figure 11: Digital Turbidity meter used

RESULTS AND DISCUSSION

Result of water quality parameters and efficiency of charcoal filter

Total dissolved solids

Before completing charcoal filtration, we determined the total dissolved solids (TDS) content in the raw water sample to be 475 mg/l. The filtration process dramatically reduced the total dissolved solids (TDS) level to 106 mg/l, (Fig. 12) demonstrating an outstanding removal efficiency of 77.68% (Table 1). The significant decrease highlights charcoal filtration's efficiency in absorbing and removing dissolved organic and inorganic contaminants from water. Charcoal efficiently captures pollutants by adsorption, utilizing its porous structure and extensive surface area, causing molecules to stick to the carbon surface. This procedure specifically focuses on eliminating contaminants such as organic compounds, chlorine, and other dissolved particles, resulting in an enhancement of the overall water quality. Charcoal's impressive efficiency of 77.68% demonstrates its ability to greatly improve water cleanliness for a variety of purposes, such as treating drinking water and facilitating industrial processes.

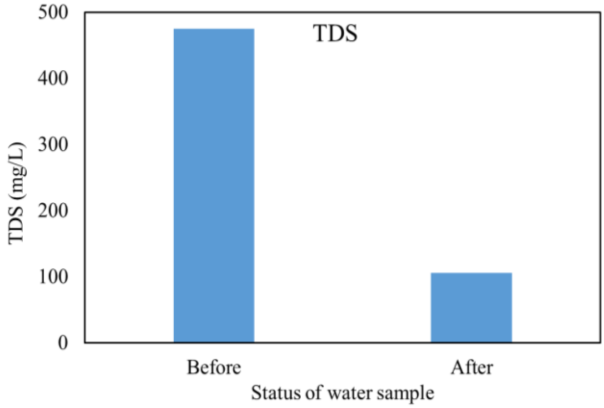

Figure 12: TDS concentrations of the water sample using a charcoal filter both before and after filtration

Biological oxygen demand

A biochemical oxygen demand (BOD) of 7 mg/l was the initial reading for the raw water sample. The BOD dropped to 3.1 mg/l following charcoal filtering (Fig. 13), showing a 55.71% reduction in organic contaminants (Table 1). By removing organic molecules, microbes, and other pollutants that contribute to biochemical oxygen demand (BOD), charcoal filtration improves water quality. This reduction is significant because lower BOD levels indicate less organic pollution and higher dissolved oxygen levels in water bodies. Charcoal's porous structure provides a large surface area for adsorption, enhancing the effectiveness of water treatment operations. Charcoal filtering is an important component of sustainable water management methods because it helps to comply with environmental regulations and ensures that the water is safe to use for a variety of purposes.

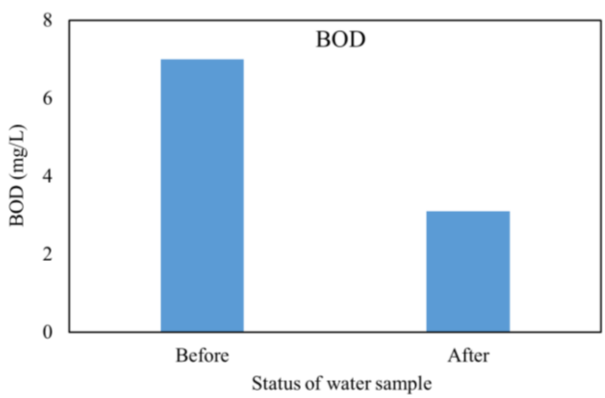

Figure 13: The biological oxygen demand (BOD) measurements were taken before and after filtration using the charcoal filter

Turbidity

The initial sample had a turbidity level of 360.0 Nephelometric turbidity units (NTU). However, after six rounds of filtration using a charcoal filter, the turbidity was significantly reduced to 15 NTU (Fig. 14). Nevertheless, this value is still above the permitted limit of 5 NTU for drinking water as defined by the World Health Organisation (WHO) in 1996. The charcoal filter is highly effective at removing turbidity, with an efficiency rate of 95.83%. Nevertheless, charcoal filtration resulted in a remarkable turbidity reduction effectiveness of 95.83% (Table 1).

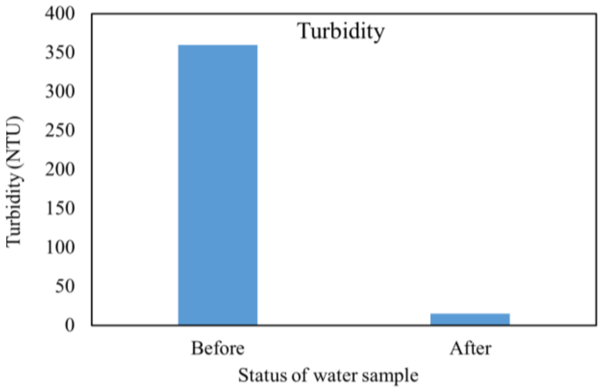

Figure 14: Turbidity concentrations in water samples before and after filtration with charcoal filter

Table 1: Efficiency of the charcoal filter used

S. No.	Parameters	Units	Efficiency
1	Total dissolved solids (TDS)	mg/L	77.68 %
2	Biological oxygen demand (BOD)	mg/L	55.71%
3	Turbidity	NTU	95.83%

CONCLUSION

Charcoal filtration effectively enhances various water quality ranges. Charcoal filtering reduced turbidity by 95.83%. Charcoal filtration removes suspended particles, making it effective at water clarification. It also reduced total dissolved solids (TDS) by 77.68%, removing dissolved pollutants from the water, as well as degraded organic pollutants by 55.71%, lowering biological oxygen demand (BOD). Charcoal filtering reduces TDS and turbidity, improving water clarity. Thus, its efficacy depends on the circumstances and customized water treatment solutions based on quality standards and environmental considerations are crucial.

Limitations of the present study

The study on "Household Wastewater Treatment with the Aid of Activated Charcoal" has several limitations. These include difficulties in applying the findings to larger systems, inconsistencies in treatment due to variations in household wastewater composition, and challenges in maintaining the long-term sustainability and upkeep of activated charcoal systems. The study may face challenges in considering a wide range of environmental circumstances as well as the impact of seasonal variations on treatment effectiveness. These considerations may influence the relevance and transferability of the study's findings to wider wastewater treatment methods and various geographical settings.

Future scope of the study

Based on the comprehensive findings of this investigation, the following recommendations were proposed: To enhance the effectiveness of eliminating turbidity and microbiological pollutants, it is advisable to blend charcoal material with other filter materials that have better filtration capability. We should conduct further research to evaluate the effectiveness of charcoal in eliminating additional pollutants like nitrates and sulphates, which this study did not investigate.

Declaration of competing interest

The authors declare that they have no know competing interests or personal relationships that could have appeared to influence the work reported in this paper.

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