UTILIZATION OF WASTE BIOMASS FOR WATER PURIFICATION

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ABSTRACT

Water purification faces significant challenges as conventional methods struggle to address escalating environmental concerns. This study explores an innovative solution using biochar, a sustainable material derived from waste cotton stems, to improve water quality. Focusing on the polluted Musi River, biochar produced at three temperatures—500°C, 600°C, and 700°C—within a sophisticated filtration system. The study unfolded in two phases: biochar production and water filtration. In the first phase, Musi River water samples and cotton stems were collected, with the stems sorted by hardness and processed through cutting, drying, and powdering. The powdered material underwent pyrolysis at specified temperatures, producing biochar with distinct temperature-dependent properties. To enhance adsorption capacity, the biochar was modified with KOH, improving its ability to remove contaminants. The biochar was stored under controlled conditions to maintain its effectiveness.

The second phase focused on water filtration using layered column systems comprising cotton, sand, gravel, and biochar from the different temperature treatments. Results demonstrated significant improvements in water quality. Biochar produced at 700°C effectively reduced turbidity, indicating superior particulate removal, while the sample from 600°C achieved notable reductions in electrical conductivity, showcasing its efficiency in minimizing dissolved ions. Alkalinity and hardness varied across treatments, revealing the complex interactions between biochar and water constituents. Overall, the findings highlight biochar's potential as a scalable and eco-friendly water purification solution. By leveraging biochar's adsorption properties, this study provides a pathway for addressing water pollution sustainably and offers valuable insights for future research and practical applications in environmental remediation.

STATEMENT OF THE PROBLEM

- According to a report by NITI Aayog, the best estimates indicate that India's water demand will exceed supply by a factor of two by 2030
- The main cause of water pollution in India is untreated sewage, which accounts for 70% of the total pollution load.
- One of the most polluted rivers in India is the Musi River, which flows through Hyderabad, the capital city of Telangana.
- The Musi River receives about 600 million liters of sewage per day from the city, along with other pollutants, such as heavy metals, dyes, pesticides, and microplastics.
- The water quality of the Musi River is far below the acceptable standards for any use, and it has become a public health hazard and an environmental nuisance.

- The use of waste biomass such as cotton stems which are often stubble burnt causing air pollution and green house emission

AIMS & OBJECTIVES

- The primary objective of this study is to examine the impact of biochar, specifically derived from cotton stems through pyrolysis at 500°C, 600°C & 700°C for 4 days, on reducing organic contaminants in Musi River water.
- This investigation will utilize several parameters as an indicator to quantify the effectiveness of the biochar treatment.
- Furthermore, the study aims to compare the quality of the filtered water with established BOD standards, specifically tailored for various water use categories.

Introduction:

Many Rivers across the world are being polluted by domestic and industrial effluents due to wide range of pollutants. Some of the pollutants are persistent and stable environmental contaminants (Karadede-Akin and Unlu, 2007). Domestic sewage poses health related issues while industrial effluents carry along them a vide variety of toxic elements like Cd. Cr. Pb, Hg and Zn which cause significant toxicity even in trace amounts. The pollutants enter various segments of environment by anthropogenic activities as well as natural cause and degrade the surface and ground water quality and make them unfit for drinking, industrial, agricultural, recreation or other purposes (Carpenter et al., 1998; Howarth et al., 1996).

Hyderabad, the capital of Telangana, is situated on the Deccan Plateau and is renowned for its network of lakes and embankments, originally constructed during the rule of the Qutubshahi dynasty. Positioned at approximately 17° 22' northern latitude and 78° 29' eastern longitude, the sprawling metropolis covers an area of 7,100 square kilometers. The city's water needs were historically met by the Musi River, supplemented by reservoirs like Osman Sagar and Himayatsagar, built in the 1920s. Hussainsagar and Mir Alam tanks also served as vital water sources until the early 1900s.

However, due to the unregulated discharge of pollutants into these water bodies, approximately 3,245 hectares of Hyderabad's drinking water resources have been significantly affected. The city's population has experienced rapid growth, soaring from an estimated 9.5 million in 2011 to surpassing the 16 million mark by the end of 2015. Consequently, supplying adequate drinking water has become a monumental challenge for the Telangana government.

The escalating demand for water is exacerbated by urban sprawl and the pollution of local resources. Consequently, water is now being sourced from external areas such as Singur (Medak district) and the NagarjunaSagar reservoir (Krishna River), requiring pumping from distances of up to 120 kilometers. Additionally, efforts are underway to tap into the Godavari River as another water source for the city.[1]

Aquatic pollution stems from both natural phenomena and human activities. Natural sources, such as rock seepage and volcanic activity, contribute relatively minimally to pollution compared to anthropogenic sources, which primarily involve untreated domestic and industrial wastewater discharge. Sewage, a major contributor to water pollution, accounts for approximately 80% of the total pollutants, with inadequate treatment capacity for the vast amount generated. Many treatment facilities are underutilized due to operational and maintenance issues, failing to meet environmental protection standards.

In Hyderabad, numerous water bodies suffer pollution from untreated domestic and industrial effluents. The city's 18 industrial estates, once potential sources of drinking water, are now heavily polluted. Major lakes like Kazipallicheruvu, Gandigudemcheruvu, and others face significant threats due to industrial pollution. Industries such as cement mills, thermal power plants, and pharmaceuticals are notable contributors to water pollution. Small-scale industries also play a significant role, further exacerbating pollution levels.

Effluent discharge poses environmental and health risks, contaminating surface water used for irrigation and drinking. Although India has policies for pollution abatement, enforcement remains a challenge. The use of polluted water in agriculture can lead to the accumulation of toxic chemicals in the food chain, posing health risks to consumers.

Efforts to address the city's water demands must prioritize the restoration, preservation, and protection of water sources. Strict enforcement and penalties for violations are essential to safeguarding water bodies. Measures to prevent industries from dumping untreated waste into lakes and embankments are crucial. Overall, stringent regulations and proactive policies are necessary to alleviate stress on water availability and meet demand in Hyderabad.

Pollution of Musi River:

The Musi River, once a pristine water body, has now become one of the most polluted rivers in Hyderabad. The pollution of the Musi River is primarily attributed to anthropogenic activities, including industrial discharge, untreated sewage, agricultural runoff, and solid waste dumping. As industries mushroomed along its banks, effluents containing heavy metals, chemicals, and organic pollutants were indiscriminately discharged into the river, severely contaminating its waters. Additionally, the discharge of untreated sewage from households and commercial establishments further deteriorates the water quality, contributing to high levels of bacterial contamination and nutrient enrichment. Moreover, agricultural runoff, carrying pesticides and fertilizers, adds to the pollution burden of the Musi River. The indiscriminate dumping of solid waste, including plastics and other non-biodegradable materials, exacerbates the pollution problem, clogging waterways and degrading aquatic habitats.

Why We Chose Musi River:

We chose the Musi River as the focus of our research for several reasons. Firstly, its proximity to our college provided us with easy access to conduct fieldwork and sample collection. Secondly, the Musi River's status as one of the most polluted rivers in Hyderabad presented a pressing environmental issue that warranted attention and intervention. By studying the pollution sources and dynamics of the Musi River, we aimed to contribute to efforts aimed at restoring and conserving this vital water body. Additionally, raising awareness about the pollution of the Musi River among the college community and the general public was an essential aspect of our research.

The pollution of the Musi River is a significant environmental challenge that demands immediate attention and concerted efforts from all stakeholders. By understanding the pollution sources and conducting research to improve water quality, we can work towards restoring the ecological health of the Musi River and ensuring its sustainability for future generations. It is imperative to implement effective pollution control measures, promote sustainable practices, and enhance public awareness to mitigate the pollution of the Musi River and safeguard its invaluable ecosystem services.

Sources of Pollution:

The pollution of the Musi River stems from various human activities along its banks and catchment area. Industrial discharge is a significant contributor, with numerous industries releasing effluents containing heavy metals, toxic chemicals, and organic pollutants directly into the river. Additionally, untreated sewage from households and commercial establishments flows unabated into the river, introducing pathogens and organic matter that degrade water quality. Agricultural runoff, carrying pesticides, fertilizers, and sediment from nearby farms, further exacerbates pollution levels, leading to nutrient enrichment and contamination. Furthermore, improper disposal of solid waste, including plastics and non-biodegradable materials, adds to the pollution burden by clogging waterways and disrupting aquatic ecosystems.

Stubble Burning in Northern States of India:

Stubble burning, also known as crop residue burning, refers to the practice of setting ablaze the leftover stalks, straw, and other agricultural residues after harvesting crops such as rice, wheat, and sugarcane. This widespread practice is prevalent in agricultural regions worldwide, but it has particularly severe consequences in areas like Punjab, Haryana, and Delhi in India.

In the states of Punjab and Haryana, which are known as the "breadbaskets of India," farmers typically cultivate rice and wheat in the Kharif and Rabi seasons, respectively. After the harvest, farmers are left with significant amounts of crop residue on their fields. Due to time constraints between the harvesting of one crop and the sowing of the next, many farmers resort to stubble burning as a quick and cost-effective method of clearing their fields to prepare for the next planting season.

While stubble burning may seem like a convenient solution for farmers, it has dire consequences for the environment, public health, and the economy:

1. Air Pollution: Stubble burning releases large quantities of harmful pollutants into the atmosphere, including particulate matter (PM2.5 and PM10), carbon monoxide (CO), volatile organic compounds (VOCs), and greenhouse gases such as carbon dioxide (CO_2) and methane (CH_4). These pollutants degrade air quality and contribute to the formation of smog, leading to respiratory issues, cardiovascular diseases, and other health problems among residents.

2. Regional Impact: The burning of crop residues in Punjab and Haryana significantly impacts air quality not only in these states but also in neighboring regions, including the National Capital Region (NCR) encompassing Delhi. During the post-harvest season, stubble burning exacerbates the already poor air quality in Delhi, amplifying the severity of air pollution and increasing the risk of respiratory illnesses and other health complications for millions of people.

3. Economic Costs: The environmental and health impacts of stubble burning entail substantial economic costs. The degradation of air quality due to stubble burning leads to productivity losses, increased healthcare expenses, and adverse effects on tourism and outdoor recreational activities. Moreover, poor air quality hampers economic growth and deters investment in affected regions.

In recent years, the reduction in air quality index (AQI) levels in Delhi during the post-harvest season has been attributed primarily to stubble burning in Punjab and Haryana. The AQI, a measure of air pollution levels, often reaches hazardous levels during this period, prompting authorities to implement emergency measures such as the temporary closure of schools, restrictions on vehicular movement, and the distribution of face masks to mitigate the health risks posed by air pollution.

Efforts to address the issue of stubble burning include government initiatives to incentivize alternative methods of crop residue management, such as mechanized harvesting, mulching, composting, and the use of specialized machinery like Happy Seeders and straw balers. Additionally, awareness campaigns, financial incentives, and support for farmers to adopt sustainable agricultural practices can help reduce reliance on stubble burning and mitigate its adverse environmental and health impacts. Ultimately, concerted efforts from policymakers, farmers, environmentalists, and other stakeholders are essential to address the complex challenges associated with stubble burning and promote sustainable agricultural practices for the well-being of both the environment and society.

Using stubble for purifying water:

In recent years, the issues of water and air pollution have become increasingly prominent environmental concerns, particularly in agricultural regions like Punjab, Haryana, and Delhi. Stubble burning, a common practice among farmers to clear fields after harvesting crops, contributes significantly to air pollution. However, innovative solutions utilizing pyrolysis reactors offer a promising approach to address both water and air pollution simultaneously. By converting cotton stubble, a prevalent agricultural waste, into biochar through pyrolysis, we can mitigate the adverse effects of stubble burning while producing a valuable resource for water purification.

Cotton is one of the largest grown crops in India, particularly in states like Punjab and Haryana. After harvesting cotton, farmers are left with significant amounts of stubble, which is often burned in open fields, contributing to air pollution. However, instead of burning cotton stubble, it can be effectively utilized for biochar production through pyrolysis. Pyrolysis is a thermochemical process that converts organic materials, such as agricultural waste, into biochar, a highly porous form of activated carbon.

Moreover, converting cotton stubble into biochar through pyrolysis offers a multitude of environmental benefits. By preventing the release of harmful pollutants into the atmosphere, this process contributes to a reduction in air pollution levels, thereby safeguarding the health and well-being of local communities. Additionally, biochar serves as an invaluable soil amendment, enhancing soil fertility, water retention, and nutrient availability. These improvements promote sustainable agriculture practices and ultimately enhance crop productivity, contributing to food security and economic development.

Furthermore, biochar produced from cotton stubble proves highly effective in water purification applications. With its exceptional porosity and surface area, biochar exhibits remarkable adsorption properties, capable of removing contaminants such as heavy metals, pesticides, and organic pollutants from water sources. By utilizing biochar as a filtration medium, we can significantly improve water quality and ensure the provision of safe drinking water, thus safeguarding public health and environmental integrity.

Lastly, the conversion of cotton stubble into biochar presents lucrative economic opportunities for farmers and entrepreneurs alike. Establishing pyrolysis facilities for biochar production enables farmers to generate additional income streams from their agricultural waste, thereby augmenting their livelihoods and bolstering rural economies. Moreover, the rising market demand for biochar as a soil amendment and water purification agent creates avenues for the commercialization of biochar products, further stimulating economic growth and innovation in the agricultural sector.

In conclusion, the utilization of cotton stubble for biochar production holds immense potential for addressing environmental, agricultural, and economic challenges in India. By harnessing this abundant agricultural waste resource, we can mitigate air and water pollution, enhance soil fertility, and create economic opportunities for rural communities. Embracing sustainable practices such as biochar production represents a crucial step towards building a resilient and environmentally conscious agricultural sector in India.

REVIEW OF LITERATURE

Biomass:

Biomass refers to organic matter derived from living or recently living organisms, such as plants, animals, and microorganisms. It is a renewable and sustainable energy source that can be converted into various forms of energy, including heat, electricity, and biofuels. Biomass can be sourced from a wide range of feedstocks, including agricultural residues, forestry waste, animal manure, and dedicated energy crops.

Types of Biomass:

Agricultural Biomass: This category encompasses crop residues, such as corn stover, wheat straw, rice husks, and sugarcane bagasse, as well as by-products from agricultural activities, such as animal manure and poultry litter.

Forestry Biomass: Forestry biomass includes residues from forest management activities, such as logging residues, forest thinning, and tree pruning, as well as wood processing industries, such as sawmills, pulp mills, and paper mills.

Municipal Solid Waste (MSW): MSW contains organic materials derived from households, businesses, and institutions, including food scraps, yard waste, paper products, and wood waste. These organic fractions can be utilized for energy production through various processes.

Dedicated Energy Crops: Certain crops, known as energy crops, are grown specifically for biomass energy production. Examples include switchgrass, miscanthus, willow, and hybrid poplar, which are characterized by their rapid growth, high biomass yields, and suitability for bioenergy conversion.nd dedicated energy crops.

Biomass, often lauded as a renewable and sustainable energy source, carries several negative impacts and challenges that warrant careful consideration. One significant concern lies in air pollution, as the combustion of biomass can release harmful pollutants such as particulate matter, carbon monoxide, nitrogen oxides, and volatile organic compounds, contributing to respiratory illnesses and cardiovascular diseases among nearby populations.

Moreover, certain biomass energy production processes, including combustion and gasification, can emit greenhouse gases such as carbon dioxide, methane, and nitrous oxide, potentially exacerbating climate change. Additionally, large-scale cultivation of energy crops for biomass production can lead to deforestation, habitat loss, and biodiversity degradation, as well as competition for arable land with food crops, exacerbating food security concerns. Furthermore, biomass cultivation and processing operations can necessitate significant water consumption and result in water pollution from agricultural runoff, posing risks to water resources and ecosystems.

The resource-intensive nature of biomass energy production, coupled with economic uncertainties and land-use conflicts, further complicates its viability as a sustainable energy solution. Thus, while biomass holds promise as an alternative to fossil fuels, it is imperative to address these negative impacts through sustainable practices, comprehensive assessments, and stakeholder engagement to ensure that biomass utilization contributes positively to environmental and societal well-being.[3]

Biochar:

Biochar is a form of charcoal produced from the pyrolysis or thermal decomposition of organic biomass in the absence of oxygen. It is a highly porous carbonaceous material with a stable structure and a large surface area, making it an effective adsorbent for a wide range of contaminants. Biochar has been used for centuries as a soil amendment to improve soil fertility and enhance crop yields. However, recent research has highlighted its potential applications in environmental remediation, wastewater treatment, and carbon sequestration.

The production of biochar involves subjecting biomass feedstocks to high temperatures (typically between 350°C and 800°C) in a controlled environment with limited oxygen. This process, known as pyrolysis, breaks down the organic matter into a mixture of gases, liquids, and solids, with biochar being the solid residue. The properties of biochar, such as its porosity, surface area, and chemical composition, depend on various factors, including the feedstock type, pyrolysis conditions, and post-treatment processes.[4]

Biochar exhibits excellent adsorption properties due to its highly porous structure and large surface area. It can effectively adsorb a wide range of contaminants, including heavy metals, organic pollutants, and nutrients, from air, water, and soil. Additionally, biochar can enhance soil fertility and nutrient retention by providing a habitat for beneficial microorganisms and improving soil structure.

In environmental remediation applications, biochar can be used to mitigate soil and water pollution by adsorbing contaminants and reducing their mobility and bioavailability. In wastewater treatment, biochar-based filtration systems can remove pollutants and improve water quality, thereby safeguarding public health and environmental integrity.

Forces of Biochar:

Biochar, a carbon-rich material derived from the pyrolysis of biomass, exhibits various forces and mechanisms that contribute to its efficacy in water purification. These include:

Physical Adsorption: Biochar possesses a highly porous structure with a large surface area, providing ample sites for physical adsorption of contaminants. Molecules from water are attracted to the surface of biochar through weak van der Waals forces, resulting in their immobilization within the pores of the material.

Chemical Adsorption: Functional groups present on the surface of biochar, such as hydroxyl (-OH), carboxyl (-COOH), and phenolic (-C6H5OH) groups, participate in chemical adsorption. Contaminants form chemical bonds with these functional groups, leading to their removal from the aqueous solution through covalent or ionic interactions.

Electrostatic Interactions: Biochar may exhibit electrostatic interactions with charged contaminants present in water. For instance, biochar with a net positive or negative surface charge can attract and adsorb oppositely charged ions through electrostatic forces.

Ion Exchange: Biochar possesses ion exchange capacity due to the presence of exchangeable cations and anions on its surface. These exchangeable ions can interact with and remove pollutants from water by exchanging them with ions present in the solution.

Surface Complexation: Certain contaminants, such as heavy metals, may form surface complexes with specific functional groups on the biochar surface. Surface complexation involves the formation of stable complexes between the contaminant ions and functional groups, resulting in their immobilization on the biochar surface.

Pore Entrapment: The intricate pore structure of biochar allows for the entrapment of contaminants within its pores. As water flows through the biochar matrix, contaminants may become physically trapped within the pores, leading to their removal from the aqueous phase.

Microbial Activity: Biochar can serve as a habitat for beneficial microorganisms that contribute to water purification processes. Microbial activity on the surface of biochar may involve the degradation or transformation of organic pollutants, thereby reducing their concentration in water.

Overall, the diverse forces and mechanisms exhibited by biochar, including physical adsorption, chemical adsorption, electrostatic interactions, ion exchange, surface complexation, pore entrapment, and microbial activity, synergistically contribute to its effectiveness as a water purification agent. By harnessing these properties, biochar offers a sustainable and cost-effective solution for mitigating water pollution and improving water quality.

Activated carbon:

Activated carbon (AC) stands as a cornerstone in water and wastewater treatment, renowned for its remarkable adsorptive properties. The genesis of AC traces back to the late 18th century when the exceptional adsorptive qualities of charcoal were first recognized. Today, AC is derived from various carbonaceous materials such as wood, coal, lignite, and coconut shell, boasting high surface area and intricately developed pore structures.[5]

1. **Surface Chemistry and Functional Groups:**

The efficacy of AC in pollutant adsorption hinges on its surface chemistry and the presence of functional groups. These functional groups, including carboxyl, carbonyl, phenols, lactones, and quinones, play a pivotal role in pollutant removal. Their existence is influenced by factors like activation processes, precursor materials, thermal treatment, and post-chemical treatment.

2. **Modification Methods:**

Researchers incessantly explore novel modification techniques to augment AC's efficacy for specific pollutants. Diverse modification methods, ranging from acidic and basic treatments to impregnation, ozone, surfactant, plasma, and microwave treatments, are employed. These methods aim to introduce tailored functional groups onto the AC surface, thereby amplifying its adsorption capabilities.

3. **Acidic Treatment:**

Acid treatment serves to oxidize the porous carbon surface, augment acidic properties, eliminate mineral elements, and heighten hydrophilicity. Nitric acid and sulfuric acid are commonly utilized for this purpose. Acidic functional groups, like carboxyl groups, exhibit efficacy in heavy metal removal from water.

4. **Adsorption Studies:**

Adsorption studies encompass the removal of heavy metals, dyes, and phenols using modified ACs. The choice of modification method significantly influences AC's adsorption capacity and efficiency for specific contaminants. Surface modifications have been shown to bolster adsorption efficiency for pollutants such as Cr(VI), Cd(II), Hg(II), dyes, and phenols.

5. **Influence of pH and Other Factors:**

The adsorption behavior of AC is profoundly influenced by solution pH, with different pollutants exhibiting varying responses to pH alterations. The paper delves into the impact of pH on the adsorption of metals, dyes, and phenols, underscoring the significance of environmental conditions in adsorption processes.

The scientists studied the breakdown of agricultural residues like corn cob, wheat straw, rice straw, and rice husk at different temperatures. They found that as temperature increased, the amount of bio-oil produced first increased then decreased, while gas production went up. Corn cob and rice husk gave more bio-oil at higher temperatures (450°C) compared to wheat and rice straw (400°C). The study also showed that the bio-chars had more carbon, making them good for making activated carbon. They used various methods to analyze the bio-oils and found they contained many oxygen-rich compounds, with the composition varying slightly depending on the biomass and pyrolysis temperature.

Conversion of Biomass to Biochar – Pyrolysis:

The process of converting corn cob, wheat straw, rice straw, and rice husk into biochar involves a method known as pyrolysis. Pyrolysis is a thermal decomposition process in the absence of oxygen, which results in the conversion of organic materials into a carbon-rich and porous material known as biochar. Here's a general overview of the steps involved and how biochar can be used for water purification:[6]

Pyrolysis Process:

1. **Feedstock Preparation:**

Collect and prepare the agricultural residues (corn cob, wheat straw, rice straw, rice husk) by cleaning and drying them to reduce moisture content. The feedstock should be chopped or ground into smaller pieces to ensure uniform pyrolysis.

2. **Loading the Pyrolysis Reactor:**

Place the prepared feedstock into a pyrolysis reactor. The reactor is designed to operate in the absence of oxygen to prevent combustion and ensure the production of biochar.

3. **Heating and Decomposition:**

Heat the reactor to initiate the pyrolysis process. As the temperature increases, organic materials in the feedstock undergo thermal decomposition, producing gases (syngas) and leaving behind the solid biochar.

4. **Cooling and Collection:**

Cool the gases produced during pyrolysis to condense them into liquid form (bio-oil) and collect them. The remaining solid material is the biochar, which is then cooled and collected for further processing.

Water Purification through Biochar:

Biochar, with its unique porous structure and adsorption capabilities, serves as a promising tool for water purification. The porous nature of biochar provides a vast surface area for adsorption, enabling it to effectively capture and retain contaminants from water. This adsorption mechanism involves physical interactions such as van der Waals forces, electrostatic interactions, and chemical bonding, allowing biochar to remove a variety of pollutants including heavy metals, dyes, organic compounds, and nutrients.

Mechanisms of Contaminant Removal:

Physical Adsorption: Biochar's porous structure provides a large surface area for physical adsorption of contaminants. This mechanism involves the binding of contaminants to the surface of biochar through weak forces such as van der Waals interactions.

Chemical Adsorption: Functional groups present on the surface of biochar, including hydroxyl (-OH), carboxyl (-COOH), and phenolic (-C6H5OH) groups, facilitate chemical adsorption of contaminants. Chemical bonds are formed between the functional groups and the contaminants, leading to their removal from the water.

Ion Exchange: Biochar possesses ion exchange capacity due to the presence of exchangeable cations and anions on its surface. Contaminants with similar charge characteristics can be exchanged with ions present on the biochar surface, effectively removing them from the water.

Types of Contaminants Removed:

Heavy Metals: Biochar is highly effective in removing heavy metals such as lead, cadmium, mercury, and arsenic from water. These metals are adsorbed onto the biochar surface through physical and chemical mechanisms.

Organic Compounds: Biochar can also adsorb organic pollutants like pesticides, herbicides, and industrial chemicals. The porous structure and surface functional groups of biochar facilitate the adsorption of these organic compounds.

Nutrients: Excessive nutrients such as nitrates and phosphates can lead to water quality issues. Biochar can adsorb these nutrients, helping to mitigate eutrophication and algal blooms in water bodies.

Factors Affecting Adsorption Efficiency:

Particle Size and Surface Area: Finely ground biochar with a larger surface area exhibits higher adsorption capacity compared to larger particles.

pH: The pH of the water can influence the surface charge of biochar and the ionization of contaminants, affecting adsorption efficiency.

Contact Time: Longer contact time between biochar and water allows for more extensive adsorption of contaminants.

Temperature: Adsorption efficiency may vary with temperature, with higher temperatures generally promoting faster adsorption kinetics.

Regeneration and Reusability:

Biochar can be regenerated after adsorbing contaminants, allowing for multiple cycles of use. Regeneration methods include washing, thermal treatment, and chemical regeneration.Regenerated biochar can retain its adsorption capacity, making it a cost-effective and sustainable option for water purification.

Environmental Sustainability

The use of biochar for water purification contributes to environmental sustainability by utilizing agricultural waste or biomass residues as a raw material.Biochar production and application can help mitigate greenhouse gas emissions by sequestering carbon and reducing the need for chemical water treatment methods.

Commercial Applications:

Biochar-based water purification systems are increasingly being adopted in commercial and industrial settings, including municipal water treatment plants, wastewater treatment facilities, and decentralized water purification units.

The versatility and effectiveness of biochar in removing a wide range of contaminants make it an attractive option for addressing water quality challenges globally.In summary, water purification using biochar offers a sustainable, cost-effective, and environmentally friendly approach to mitigating water pollution and ensuring access to clean water resources. As research and technological advancements continue, biochar-based solutions are expected to play an increasingly significant role in addressing water quality issues worldwide.

Difference between Activated Carbon and Charcoal:

Characteristics	**Activated carbon**	**Charcoal**
Production Process	Produced by heating carbon-rich materials with a gas or chemical activation process, creating a highly porous structure.	Produced by heating wood, peat, coconut shells, or other organic materials in the absence of air.
Pore Structure	Has a highly developed porous structure with a large surface area, which increases its adsorption capacity	Has a less developed porous structure compared to activated carbon.
Adsorption Capacity	High adsorption capacity due to the large surface area and porous structure, making it effective for various applications.	Lower adsorption capacity compared to activated carbon
Usage	Widely used in various industries for water purification, air and gas filtration, medical applications, and as an adsorbent in chemical processes.	Primarily used for cooking, heating, and as a fuel source. Also used in art for drawing and writing.
Reusability	May be regenerated and reused in certain applications after reaching saturation.	Generally, not designed for regeneration and reuse in the same way as activated carbon

PREPARATION OF BIOCHAR:

1. **Collection and Preparation of Waste Cotton Stems:**
   - Waste cotton stems were meticulously collected from local sources, ensuring they were free from any visible contaminants or impurities.
   - Upon collection, the stems underwent thorough cleaning to remove any dirt or debris.
   - The cleaned stems were then cut into smaller pieces to facilitate the subsequent processing steps.
2. **Drying and Milling:**
   - The cut cotton stems were subjected to a drying process to remove excess moisture content, enhancing their suitability for further processing.
   - Once adequately dried, the stems were finely powdered using a high-precision multimill, ensuring uniform particle size and consistency.
3. **Preparation of Pyrolysis Setup:**
   - A specialized pyrolysis setup was assembled, comprising a quartz tube equipped with ceramic beads and cotton as a support medium.
   - The quartz tube was meticulously cleaned and prepared to ensure optimal conditions for the pyrolysis process.

4. **Pyrolysis Process:**
- The powdered cotton stem samples were carefully inserted into the quartz tube, ensuring uniform distribution.
- The pyrolysis reactor was set to three distinct temperatures: 500°C, 600°C, and 700°C, each representing varying pyrolysis conditions.
- The pyrolysis process was initiated and allowed to proceed for an appropriate duration at each temperature, ensuring thorough conversion of the biomass into biochar.

5. **Collection of Biochar:**
- Upon completion of the pyrolysis process, the biochar produced at each temperature was meticulously collected in separate containers, avoiding cross-contamination.

6. **Modification with KOH:**
- To enhance the adsorption capacity of the biochar, a modification process was conducted using potassium hydroxide (KOH).
- The biochar samples were carefully treated with KOH solution, ensuring uniform coating and distribution of the modifying agent.

7. **Storage and Preservation:**
- The prepared and modified biochar samples were stored in designated containers in a dry and cool environment, safeguarding them from moisture and direct sunlight.
- Proper labeling and documentation were maintained to ensure traceability and facilitate subsequent analysis or experimentation.

Quality Control and Analysis:

Quality control measures were implemented throughout the process to ensure the integrity and efficacy of the biochar samples.Post-processing analysis, including characterization studies and adsorption tests, was conducted to evaluate the performance of the modified biochar and ascertain its suitability for various applications.

Visual Inspection:

Visual examination of the waste cotton stems to ensure they are free from visible contaminants or impurities.

Inspection of the powdered samples for uniformity of particle size and absence of foreign matter.

Moisture Content Analysis:

Measurement of the moisture content of the waste cotton stems before and after the drying process to ensure optimal moisture levels for pyrolysis.

Temperature Monitoring:

Continuous monitoring of the pyrolysis reactor temperatures to ensure consistency and adherence to the specified temperature profiles.

Duration of Pyrolysis:

Control of the duration of the pyrolysis process to ensure sufficient conversion of biomass into biochar while avoiding over- or under-pyrolysis.

Sample Collection Protocol:

Adherence to strict protocols for collecting biochar samples at different stages of the pyrolysis process to avoid cross-contamination and ensure representative sampling.

Chemical Analysis:

Analysis of the elemental composition of the produced biochar using techniques such as X-ray fluorescence (XRF) or elemental analysis to assess purity and composition.

Adsorption Capacity Testing:

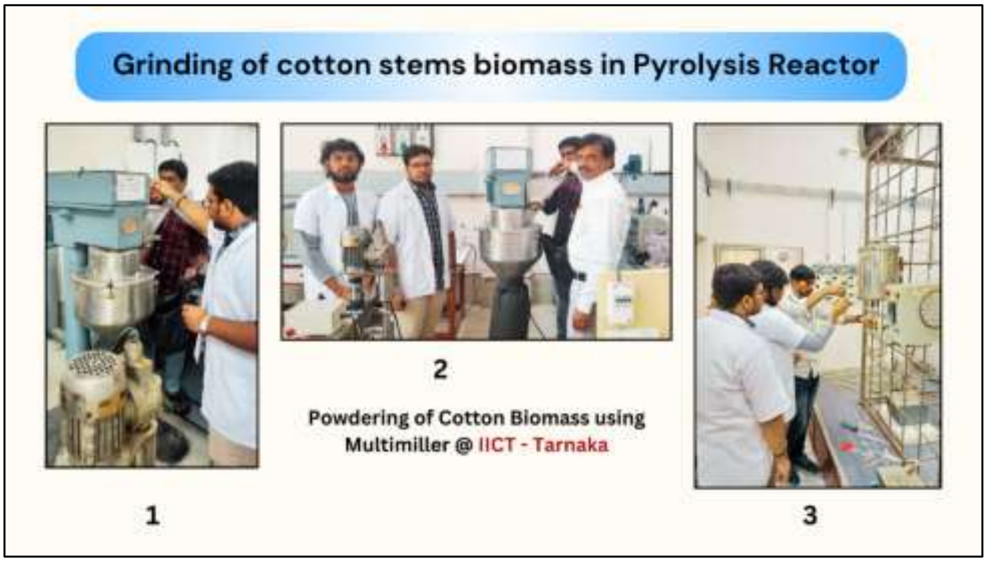
Evaluation of the adsorption capacity of the modified biochar through adsorption studies using standard contaminants or model pollutants.

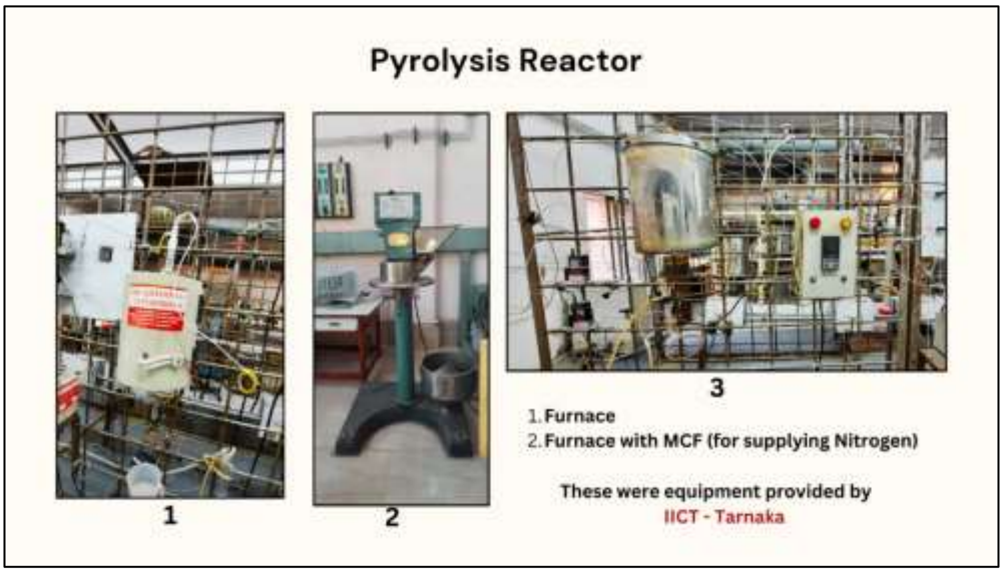
Storage Conditions:

Monitoring and maintenance of proper storage conditions, including temperature, humidity, and exposure to light, to prevent degradation or contamination of the biochar samples.

1. Collection of Cotton stems

2. Cotton stems





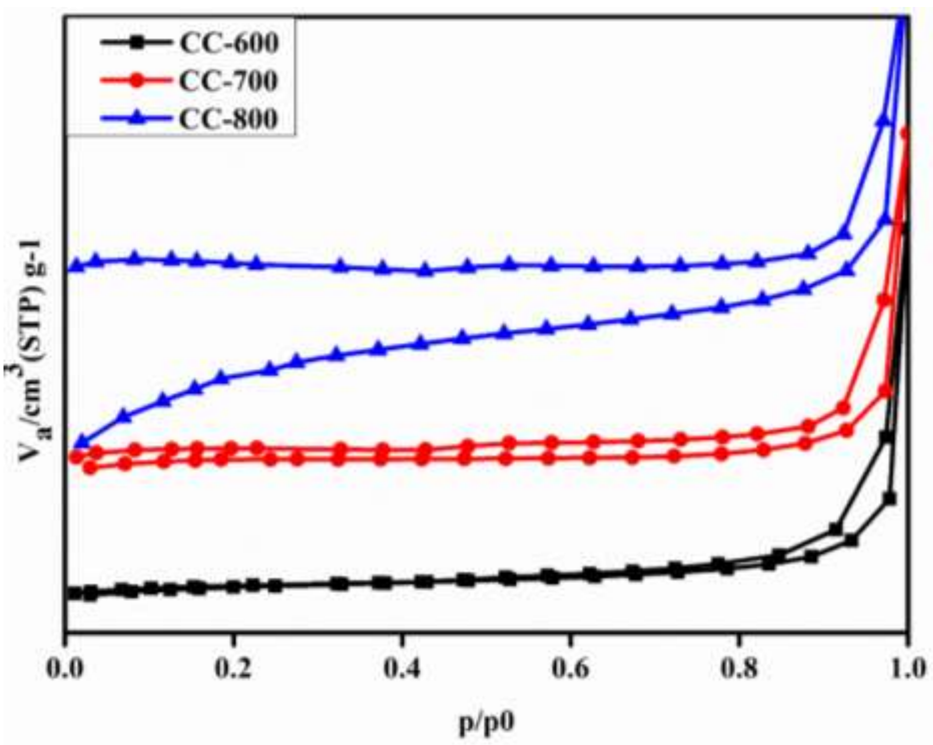
BET ANALYSIS OF BIOCHAR

S. No	Catalyst	BET Surface Area (m^2/g)	Total Pore Volume (cm^3/g)	Average Pore Diameter (nm)
1	CC-500	1.78	0.0129	29.10
2	CC-600	2.48	0.0125	20.19
3	CC-700	15.47	0.0226	5.86

Table: Catalyst Properties Analysis for Biochar Production

- The provided table presents the results of BET surface area analysis conducted on biochar activated carbon produced for water purification, categorized under three catalysts: CC-500, CC-600, and CC-700.

- It is observed that as the pyrolysis temperature increases from 500°C to 700°C, there is a significant enhancement in the BET surface area of the biochar catalysts. Specifically, the BET surface area increases from 1.78 m^2/g for CC-500 to 15.47 m^2/g for CC-700.
- This increase in surface area with higher pyrolysis temperatures indicates a corresponding increase in the number of pores within the biochar structure, which is a favorable characteristic for water purification processes.
- The total pore volume of the biochar catalysts also demonstrates a notable increment with elevated pyrolysis temperatures, ranging from 0.0129 cm^3/g for CC-500 to 0.0226 cm^3/g for CC-700.
- Additionally, the average pore diameter of the biochar catalysts decreases as the pyrolysis temperature rises. This suggests that the pores become finer and more densely packed with increasing temperature, enhancing the adsorption capacity of the biochar for water purification applications.
- The findings imply that biochar produced at higher pyrolysis temperatures possesses superior adsorption properties, making it more effective in removing contaminants from water sources.



PURIFICATION OF WATER USING BIOCHAR

1. **Selection of Collection Site:**
- Waste water samples were collected from the Musi River flowing in front of Government City College, ensuring a representative sample of the local water body.
2. **Preparation of Filtration Column:**
- A clean column was carefully chosen for the filtration experiment to ensure it was free from any potential contaminants or residues.
3. **Layering Setup:**
- At the bottom of the column, a layer of cotton was placed to serve as a primary filter, capturing large debris and sediment.

- A layer of gritty sand was added on top of the cotton, acting as a secondary filter to remove finer particles and impurities.

4. **Incorporation of Biochar Layers:**

- Biochar produced at varying temperatures (500°C, 600°C, 700°C) was sequentially added to the column in layers.
- Each layer of biochar served as an adsorbent, capturing dissolved contaminants and pollutants present in the water.

5. **Final Layer and Repetition:**

- Gravel was placed as the final layer atop the biochar layers to facilitate uniform water flow and prevent clogging.
- The layering sequence of cotton, sand, biochar, and gravel was repeated until the column was adequately filled, ensuring sufficient contact between the water and the biochar adsorbents.

6. **Replication and Control:**

- The entire procedure was meticulously replicated using biochar produced at different temperatures (500°C, 600°C, 700°C) to assess the influence of pyrolysis temperature on water purification efficacy.
- Control columns without biochar were also set up to compare the effectiveness of the biochar filtration system against traditional filtration methods.

7. **Water Filtration Process:**

- Musi River water samples were poured through each biochar column system, allowing the water to percolate through the various filtration layers.
- As the water passed through the column, contaminants were adsorbed by the biochar layers, resulting in purified water exiting at the bottom of the column.

8. **Collection of Filtered Water Samples:**

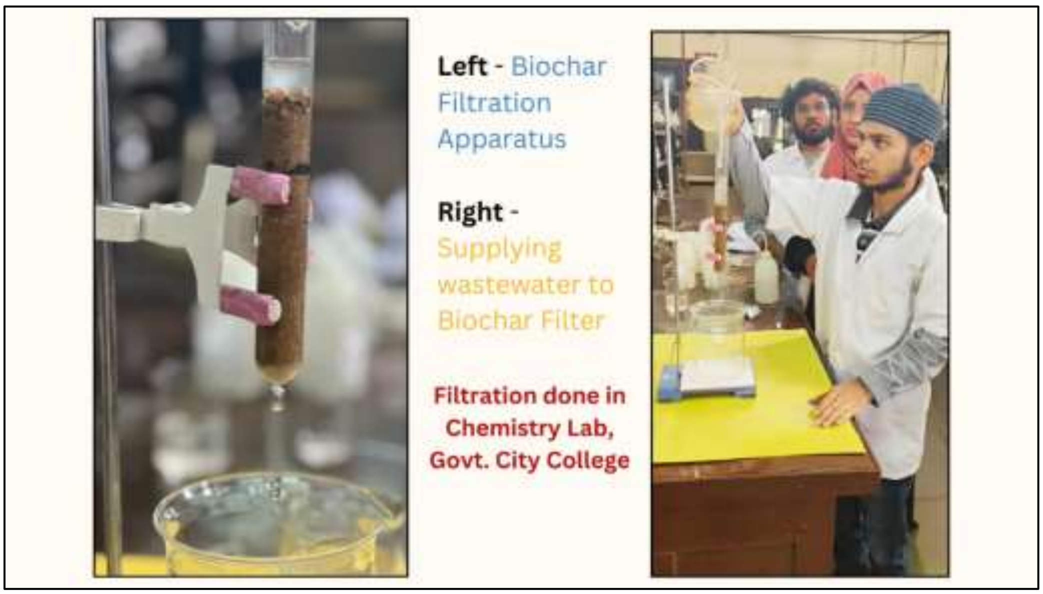
- Filtered water samples were collected at the bottom of each column system after passing through the filtration layers.
- These samples were then analyzed to evaluate the efficiency of the biochar filtration system in removing contaminants and improving water quality.

9. **Monitoring and Analysis:**

- Throughout the filtration process, parameters such as flow rate, pressure, and turbidity were monitored to assess the performance of the biochar column system.
- Post-filtration water samples were subjected to comprehensive analysis to quantify the reduction in contaminant levels and determine the overall effectiveness of the filtration setup.

10. **Data Recording and Interpretation:**

- Detailed records of experimental conditions, observations, and results were maintained to ensure reproducibility and facilitate data analysis.
- The collected data was analyzed to draw conclusions regarding the efficacy of biochar-based water purification and its potential for practical applications in wastewater treatment and environmental remediation efforts.



OBSERVATION

Tests Performed	**Techniques Used**
pH	4500 H+B value
Electrical Conductivity	2510 B value
Total Alkalinity as CaCO3	2320B Titaration method
Total Hardness as CaCO3	2340C EDTA Titrimetric method
Chloride as Cl-	4500-CΓ B Argentometric method
Fluoride as F-	4500-F C lon Selective Electrode method

Nitrate as NO3-2	4500-NO3 B Ultra Violet Spectrophotometric Screening method
Sulfate as SO4 -2	4500- (SO 4) E Spectrophotometric Method

Note: All the above tests are perfomed according to APHA 23rd Edition which is the Standard Method for the Examination of Water and Wastewater

- Biochar filtration appreciably affected pH levels, ensuring water suitability for diverse applications.
- Sample 1 exhibited minimal change, while Samples 2 and 3 showed a reduction, suggesting temperature-dependent impacts.
- Biochar filtration consistently reduced electrical conductivity, with the most significant decrease in Sample 2 (150 ml @ 600°C).This highlights biochar's efficacy in removing dissolved ions or salts, enhancing water quality.
- Biochar filtration, dependent on temperature, influenced water hardness; minimal change in Sample 1, reduced hardness in Samples 2 and 3.
- The results indicate that biochar filtration, particularly at higher temperatures, may reduce chloride levels in the water.
- Consistent results demonstrate significant nitrate reduction through biochar filtration, especially pronounced in Sample 2, indicating the efficacy of the method in mitigating nitrate content in water.
- Biochar's efficacy in reducing sulfate levels varies with temperature; higher temperatures, notably 600°C and 700°C, demonstrate increased effectiveness, establishing biochar as a valuable method for sulfate removal from water sources.

1. **pH**

   Sample 1 (150 ml @ 500°C):
   - pH Result: 7.00
   - Interpretation: The pH of this sample is neutral.

   Sample 2 (150 ml @ 600°C):
   - pH Result: 7.3
   - Interpretation: The pH of this sample is alkaline.

   Sample 3 (150 ml @ 700°C):
   - pH Result: 6.8
   - Interpretation: The pH of this sample is slightly alkaline.

   Raw Water:
   - pH Result: 5.7
   - Interpretation: The pH of the raw water sample is slightly acidic.

2. **ELECTRICAL CONDUCTIVITY**

   Sample 1 (150 ml @ 500°C):
   - Conductivity Result: 1210 µS/cm
   - Interpretation: The electrical conductivity of this sample is relatively high.

   Sample 2 (150 ml @ 600°C):
   - Conductivity Result: 860 µS/cm
   - Interpretation: The electrical conductivity of this sample is lower compared to Sample 1.

   Sample 3 (150 ml @ 700°C):
   - Conductivity Result: 1166 µS/cm

- Interpretation: The electrical conductivity of this sample is intermediate, falling between Sample 1 and Sample 2.

Raw Water:
- Conductivity Result: 1252 µS/cm
- Interpretation: The electrical conductivity of the raw water sample is relatively high.

3. **TOTAL ALKALINITY AS CaCO3**

Sample 1 (150 ml @ 500°C):
- Alkalinity Result: 410 mg/L
- Interpretation: The total alkalinity of this sample is moderate.

Sample 2 (150 ml @ 600°C):
- Alkalinity Result: 290 mg/L
- Interpretation: The total alkalinity of this sample is lower compared to Sample 1.

Sample 3 (150 ml @ 700°C):
- Alkalinity Result: 350 mg/L
- Interpretation: The total alkalinity of this sample is intermediate, falling between Sample 1 and Sample 2.

Raw Water:
- Alkalinity Result: 420 mg/L
- Interpretation: The total alkalinity of the raw water sample is relatively high.

4. **TOTAL HARDNESS as CaCO3**

Sample 1 (150 ml @ 500°C):
- Result: 320 mg/L
- Interpretation: The total hardness of this sample is similar to the raw water, suggesting that biochar filtration at 500°C did not significantly alter hardness levels.

Sample 2 (150 ml @ 600°C):
- Result: 220 mg/L
- Interpretation: The total hardness of this sample is lower compared to both the raw water and Sample 1, indicating a reduction in hardness after biochar filtration at 600°C.

Sample 3 (150 ml @ 700°C):
- Result: 220 mg/L
- Interpretation: The total hardness of this sample is also lower than the raw water, suggesting a reduction in hardness after biochar filtration at 700°C.

Raw Water:
- Result: 320 mg/L
- Interpretation: The total hardness of the raw water sample is relatively high.

5. **CHLORIDE** as Cl-

Sample 1 (150 ml @ 500°C):
- Result: 150 mg/L
- Interpretation: The chloride concentration in this sample is similar to the raw water, suggesting that biochar filtration did not significantly alter chloride levels.

Sample 2 (150 ml @ 600°C):
- Result: 102 mg/L
- Interpretation: The chloride concentration in this sample is lower compared to both the raw water and Sample 1, indicating a reduction in chloride after biochar filtration.
-

Sample 3 (150 ml @ 700°C):

- Result: 142 mg/L
- Interpretation: The chloride concentration in this sample is slightly lower than the raw water, suggesting a reduction in chloride after biochar filtration at 700°C.

Raw Water:

- Result: 153 mg/L
- Interpretation: The chloride concentration in the raw water sample is relatively high.

6. **NITRATE as NO_3^{2-}**

Sample 1 (150 ml @ 500°C):

- Result: 5.0 mg/L
- Interpretation: The nitrate concentration in this sample is lower compared to the raw water, indicating a reduction in nitrate levels after biochar filtration.

Sample 2 (150 ml @ 600°C):

- Result: 2.3 mg/L
- Interpretation: The nitrate concentration in this sample is significantly lower than the raw water, suggesting a substantial reduction in nitrate after biochar filtration

Sample 3 (150 ml @ 700°C):

- Result: 4.2 mg/L
- Interpretation: The nitrate concentration in this sample is lower than the raw water, indicating a reduction in nitrate after biochar filtration

Raw Water:

- Result: 13.2 mg/L
- Interpretation: The nitrate concentration in the raw water sample is relatively high.

7. **SULPHATE as SO_4^{2-}**

Sample 1 (150 ml @ 500°C):

- Result: 85.50 mg/L
- Interpretation: The sulfate concentration in this sample is similar to the raw water, suggesting that biochar filtration did not significantly alter sulfate levels.

Sample 2 (150 ml @ 600°C):

- Result: 62.94 mg/L
- Interpretation: The sulfate concentration in this sample is lower compared to both the raw water and Sample 1, indicating a reduction in sulfate after biochar filtration

Sample 3 (150 ml @ 700°C):

- Result: 74.76 mg/L
- Interpretation: The sulfate concentration in this sample is slightly lower than the raw water, suggesting a reduction in sulfate after biochar filtration

Raw Water:

- Result: 86.30 mg/L
- Interpretation: The sulfate concentration in the raw water sample is relatively high

8. **TURBIDITY**

Sample 1 (150 ml @ 500°C):

- Turbidity Result: 3.4
- Interpretation: The turbidity of this sample is moderate.

Sample 2 (150 ml @ 600°C):

- Turbidity Result: 4.1
- Interpretation: The turbidity of this sample is moderate to high.

Sample 3 (150 ml @ 700°C):

- Turbidity Result: 1.8

- Interpretation: The turbidity of this sample is relatively low.

Raw Water:

- Turbidity Result: 6.2
- Interpretation: The turbidity of the raw water sample is high.

9. BIOLOGICAL OXYGEN DEMAND:

Sample 1 (150 ml @ 500°C):

- BOD Result: 11 ppm
- Interpretation: The BOD level of this sample is lower compared to the raw water sample, indicating a reduction in organic pollutant concentration after filtration with biochar produced at 500°C.

Sample 2 (150 ml @ 600°C):

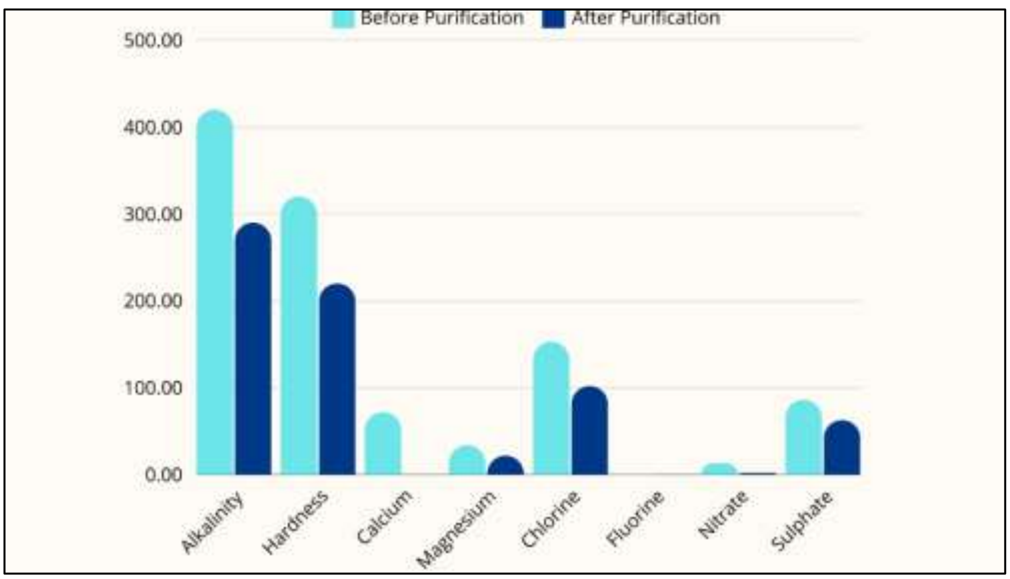
- BOD Result: 7 ppm
- Interpretation: The BOD level of this sample is further reduced compared to both Sample 1 and the raw water sample, suggesting enhanced organic pollutant removal with biochar produced at 600°C.

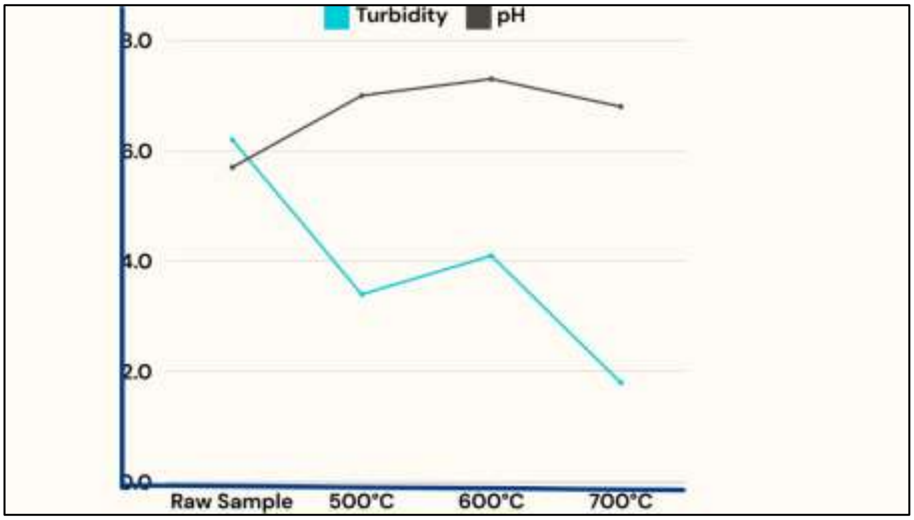
Sample 3 (150 ml @ 700°C):

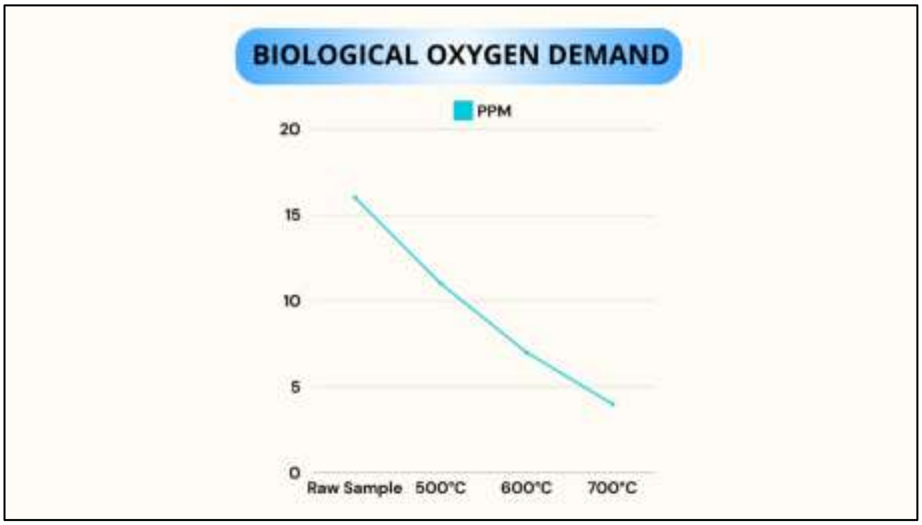
- BOD Result: 4 ppm
- Interpretation: The BOD level of this sample is the lowest among all samples, indicating the most effective removal of organic pollutants achieved with biochar produced at 700°C.

Raw Water:

- BOD Result: 16 ppm
- Interpretation: The raw water sample exhibits the highest BOD level, signifying the presence of significant organic pollutants prior to filtration with biochar.







RESULTS

- The biochar samples produced at different temperatures exhibited varied pH levels, with sample 1 (500°C) and sample 3 (700°C) showing slightly alkaline pH, sample 2 (600°C) displaying slightly acidic pH, while the raw water sample had a slightly acidic pH.
- Biochar filtration consistently lowered electrical conductivity, with the most significant reduction in Sample 2 (150 ml @ 600°C), followed by Sample 1 (150 ml @ 500°C) and then Sample 3 (150 ml @ 700°C). This indicates biochar's effective removal of dissolved ions or salts, improving water quality.
- The results indicate that biochar filtration may influence alkalinity levels, with different temperatures showing varying degrees of impact. While Sample 1 showed minimal change, Samples 2 and 3 demonstrated a reduction in alkalinity after filtration.
- The results suggest that biochar filtration can influence water hardness, with varying impacts at different temperatures. While Sample 1 showed minimal change, Samples 2 and 3 demonstrated reduced hardness levels after filtration.
- The results indicate that biochar filtration, particularly at higher temperatures, may reduce chloride levels in the water.
- The results consistently show a substantial reduction in nitrate levels after biochar filtration, with the most significant impact observed in sample 2. This suggests that biochar filtration is effective in mitigating nitrate content in water.

- Biochar's effectiveness in reducing sulfate levels depends on the type of biochar. Biochar produced at higher temperatures, specifically 600°C and 700°C, demonstrate increased efficacy in sulfate reduction, showcasing biochar as a valuable method for removing sulfates from water sources.
- The biochar filtration process resulted in a progressive decrease in turbidity levels, with the lowest turbidity achieved using biochar produced at 700°C, indicating effective removal of suspended particles from the water samples.
- The biochar filtration process resulted in a progressive reduction of biochemical oxygen demand (BOD), with the lowest BOD level achieved using biochar produced at 700°C, indicating effective organic pollutant removal from the water samples.

DISCUSSION

- The experimental biochar filtration system employing a column design with organic waste biomass demonstrates superiority in its superior filtration efficiency, enhanced contaminant removal capabilities, environmental benefits through the use of biochar, optimized water flow, versatility, and cost-effectiveness.
- The combination of effective adsorption properties, environmental friendliness, and simplicity positions this filtration method as a technically superior solution for water treatment compared to certain traditional filtration approaches.
- Utilizing biochar as a filtration medium offers a superior alternative to traditional methods, providing effective removal of contaminants from water sources.
- Biochar filtration systems demonstrate enhanced efficiency in removing various pollutants, including heavy metals, organic compounds, and suspended solids, leading to cleaner and safer water.
- The adsorptive properties of biochar enable efficient removal of contaminants, such as pesticides, pharmaceuticals, and pathogens, resulting in improved water quality and safety.
- The production and utilization of biochar for water filtration contribute to environmental sustainability by repurposing agricultural waste and reducing reliance on conventional filtration materials.
- Biochar filtration systems are designed to optimize water flow rates while maintaining high removal efficiency, ensuring consistent and reliable water output for various applications.
- Biochar filtration systems are adaptable to diverse water sources and treatment needs, making them suitable for a wide range of applications, from small-scale household purification to large-scale municipal water treatment plants.
- Implementing biochar filtration offers cost-effective solutions for water treatment, with lower operational costs compared to conventional methods. Additionally, biochar production promotes sustainable practices by utilizing renewable biomass resources.

CONCLUSION

- The successful completion of this experiment has several implications for water purification.
- The experiment has provided valuable insights into a multi-stage filtration system's effectiveness, particularly when biochar is integrated.
- Intense removal of cations like calcium and magnesium.
- The substantial reduction in nitrate levels demonstrates the potential for denitrification.
- The temperature-dependent efficacy in sulfate reduction, particularly at 600°C and 700°C, positions biochar as a valuable method for mitigating sulfate levels in water sources.
- Biochar derived from cotton stems which is a waste biomass can reduce dependence on fossil fuels and synthetic chemicals, and utilize the abundant and low cost biomass waste resources

- Further investigations into the specific mechanisms of contaminant removal, scalability of the process, and comparisons with conventional methods could provide valuable insights.
- Demonstrating the potential use of nanocellulose materials obtained from the chemical treatment of biomass as an effective agent for the removal of toxic species from water, such as heavy metals ions
- Recommendations include upgrading laboratory facilities and employing advanced analytical tools for a more comprehensive understanding of the purification process.

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