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ENGINEERING COLLEGE

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PROJECT WORK

DEPARTMENT OF CIVIL ENGINEERING

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DEPARTMENT OF CIVIL ENGINEERING
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EFFECTS OF SYNTHETIC LEACHATE ON COCONUT SHELL BIOCHAR AND COMPARATIVE STUDY ON ACTIVATED CHARCOAL

A PROJECT REPORT

submitted by

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to

the APJ Abdul Kalam Technological University

in partial fulfilment of the requirements for the award of the Degree

of

Bachelor of Technology

in

Civil Engineering

Department Of Civil Engineering

Vimal Jyothi Engineering College

Chemperi

JUNE 2023

DECLARATION

We undersigned hereby declare that the project report "Effects of Synthetic Leachate on Coconut Shell Biochar and Comparative Study on Activated Charcoal", submitted for partial fulfilment of the requirements for the award of degree of Bachelor of Technology of the APJ Abdul Kalam Technological University, Kerala is a bonafide work done by us under the supervision of Mr. Rojin P. This submission represents our ideas in our own words and where ideas or words of others have been included, we have adequately and accurately cited and referenced the original sources. We also declare that we have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in our submission. We understand that any violation of the above will be a cause for disciplinary action by the institute and the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree, diploma or similar title of any other University.

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CERTIFICATE

This is to certify that the report entitled **"Effects of Synthetic Leachate on Coconut Shell Biochar and Comparative Study on Activated Charcoal"** submitted by **Antus Sunny (VML19CE028), Anura Balakrishnan (VML19CE030), Karthik K (VML19CE059), Treesa Wilson (VML19CE099)** to the APJ Abdul Kalam Technological University in partial fulfilment of the requirements for the award of the Degree of Bachelor of Technology in Civil Engineering is a bonafide record of the project work carried out by them under our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

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ACKNOWLEDGEMENT

First and foremost, we thank god almighty who gave us strength, courage, good health and interest to begin and complete all our task successfully. We express our gratitude to respected principal, **Dr. Benny Joseph** for his permission and constant encouragement. We submit our sincere thanks respected to **Dr. Biju Mathew**, Head of Department of Civil Engineering for his support and timely suggestions. We are thankful to the project coordinator, as well as our project guide **Mr. Rojin P**, Assistant professor in Civil Engineering for his suggestions and guidance. We thank all the faculties of Civil Engineering Department for their limitless support. We profound our sincere thanks to our parents, who always pray for our progress and extend their moral and financial support for our welfare. We also thank our friends, who are with us all the time and positively supporting us in our activities.

ABSTRACT

Now a day's water scarcity is a burning issue. The world's water resources are being deteriorated due to the continuous discharge of a large number of organic and inorganic contaminants. Due to the increase in population, the demand for water also increases. Here comes the necessity of waste water treatment and removal of contaminants, thus making it a potable water. This project focuses on applications in waste water treatment using biochar to remove various pollutants such as heavy metals, chemical and organic compounds. Biochar is a lightweight black residue, made of carbon and ashes, remaining after the pyrolysis of biomass. As an emerging sorbent with great potential, biochar has shown significant advantages such as the broad sources of feed stocks, easy preparation process, and favourable surface and structural properties. Heavy metals in the water environment mostly come from anthropogenic activities such as smelting, mining, and electronic manufacturing effluents. Biochar has been suggested to be used for heavy metals removal from contaminated water. Biochar can be directly used in water and wastewater treatment as a sorbent for contaminants removal. The physical and chemical properties of biochar depend primarily on the types of feedstock and pyrolysis conditions i.e., temperature, residence time, reactor type and heating rate. Though the biochar has an excellent capability to adsorb heavy metal ions from metal contaminated solutions, this capacity is relatively lower in comparison with other known bio sorbents such as activated carbon. Hence there are several approaches to modify the biochar. The contaminated soil and water is treated with biochar and conduct batch method and column method to determine the removal efficiency of contaminants. The results of tests are to be compared and determine the efficiency of prepared biochar over other sorbents. By this comparison, it enables to utilize the biochar instead of the costly bio-sorbents.

Keywords: Biochar, waste water treatment, pyrolysis, heavy metals, sorbents

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LIST OF ABBREVIATIONS

ADS	Adsorption
ASTM	American Standard Test Method
BC	Biochar
BET	Brunauer-Emmett-Teller
COD	Chemical Oxygen Demand
CSBC	Coconut Shell Biochar
CSIF	Central Sophisticated Instrumentation Facility
DES	Desorption
GAC	Granular Activated Charcoal
PAC	Powdered Activated Charcoal
RPM	Revolutions Per Minute
UV	Ultraviolet

` CHAPTER 1

INTRODUCTION

1.1 GENERAL

Water is one of the essential need of the industry as well as life on earth. Now a day's water scarcity is a burning issue. The world's water resources are being deteriorated due to the continuous discharge of a large number of organic and inorganic contaminants. Due to the increase in population, the demand for water also increases. Here comes the necessity of waste water treatment and removal of contaminants, thus making it a potable water. For the treatment of waste water various methods are available like ion-exchange, membrane separation but this need needs more financial input due to that it restrict the use of this method. Among them adsorption by using low cost adsorbent is an effective method for waste water treatment. This project focuses on applications in waste water treatment using biochar to remove various pollutants such as heavy metals and chemical compounds. Biochar is a lightweight black residue, made of carbon and ashes, remaining after the pyrolysis of biomass.

1.2 OBJECTIVES

The project focuses on the following objectives:

- Determination of properties of biochars made from coconut shell.
- Removal of contaminants like PO_4^{3-}, NO_3^- from contaminated water.
- Conduction of batch method and column method to determine the removal efficiency of contaminants from water using biochars.
- Comparison with powdered and granular activated charcoals.

1.3 SCOPE

Nowadays, water is being polluted at a higher rate. A treatment technique with low cost is required for the sustainable treatment of water. Adsorption is a low cost technology and is able to applicable to variety of pollutants. Biochar is used to improve potential carbon sink and soil carbon storage, increase nutrients in soil retention and availability of nutrients, reduction of nutrient leachate and sustain the stability of the ecosystem of the soil. A project of this type gains much importance in a state like Kerala where there are lot of reported cases of lake pollution and polluted ponds which are abandoned.

CHAPTER 2

LITERATURE SURVEY

2.1 GENERAL

The removal of pollutants from contaminated water by using biochar is reviewed in these journals. The preparation of biochar by the pyrolysis method, their properties and their role in the removal of pollutants is studied.

2.2 LITERATURE REVIEW

Masto et al., (2013): Biochar is a useful material for carbon storage in soils. In this report, they explored conversion of water hyacinth (Eichornia crassipes) to biochar as a sustainable weed management strategy, as it also has potential for improving soil quality. The optimum condition for obtaining maxi-mum stable carbon in Eichornia biochar (EBC) is 300–350 °C temperature with 30–40 min residence time. Biochar is a useful material for carbon storage in soils. In this report, the researchers explored conversion of water hyacinth to biochar as a sustainable weed management strategy, as it also has potential for improving soil quality. Soil biochemical properties and maize seedling growth were used to investigate the effects of biochar addition to the soil. The study shows that the waste Eichornia weed could be gainfully utilised as a soil quality amendment material by converting it to EBC.

Patel et al., (2017): It illustrates the procedures of batch and column experiments on water effluent. It gives an idea about the treatment methods and result analysis. Out of the various methods available removal of pollutants on a solid body, adsorption is much effective. Based on literature survey it has been found that the removal of pollutant from effluent waste stream has been carried out by various researcher in batch mode and various kinetic data has been generated. This leaves behind an unexplored area of pollutant removal by adsorption in a continuous mode, which has been selected as a focus of present study.

Zhou et al., (2018): This study aimed to evaluate the adsorption of cadmium and copper by ferromanganese binary oxide-BC composites (FMBC). The biochar were prepared and their physiochemical properties and morphologies were also examined. Kinetic modelling and adsorption isotherms were used to characterize the adsorption of Cu (II) and Cd (II) on FMBC, revealing that adsorption was well represented by pseudo-second-order kinetics and the Langmuir isotherm model. Moreover, adsorption was favoured by increased pH and high

humic acid concentration. X-ray photoelectron spectroscopy and Fourier transform infrared analyses confirmed that the heavy metal ions adsorbed on FMBC were divalent, indicating that the uptake of Cu (II) and Cd (II) was mainly due to the formation of strong mono- or multidentate inner-sphere complexes.

Xue et al., (2019): This study prepared and evaluated seven types of food waste-based biochars (FWBBs) (including meat and bone, starchy staples, leafy stemmed vegetables, nut husks, fruit pericarp, bean dreg and tea leaves). The impacts of raw materials, pyrolysis temperatures, and residence time on the removal of ammonia nitrogen at different ammonia nitrogen concentrations (5, 10, 20, 50, 100, 150 mg/L) were investigated.

Castilla-Caballero et al., (2020): Biochars are emerging eco-friendly products showing outstanding properties in areas such as carbon sequestration, soil amendment, bioremediation, bio composites, and bioenergy. These interesting materials can be synthesized from a wide variety of waste-derived sources, including lignocellulosic biomass wastes, manure and sewage sludge. In this work, abundant data on biochars produced from coconut-shell wastes obtained from the Colombian Pacific Coast are presented. Biochar synthesis was performed varying the temperature and O2 feeding in the pyrolysis reaction. Production yields and some biochar properties such as particle size, zeta potential, elemental content (C, N, Al, B, Ca, Cu, Fe, K, Li, Mg, Mn, Na, P, S, Ti and Zn), BET surface area, FT-IR spectrum, XRD spectrum, and SEM morphology are presented.

Yaashikaa et al., (2020): It focuses on an overview of remediating harmful contaminants utilizing biochar. Production of biochar utilizing various systems has been discussed. It deals with the various methods of biochar production. Production of biochars uncovers a wide variety of biomass that have been utilized as the feedstocks and pyrolyzed by various procedures to handle water pollution. The properties of resultant biochar are significantly influenced by pyrolyis temperature, feedstock, and pyrolysis technology. Biochar can be utilized as major source for removal of toxic pollutants.

Das et al., (2021): It investigates the effect of pyrolysis reactors on the properties of biochar by keeping factors such as feedstock, carbonisation temperature, heating rate and residence time constant. It focuses on the composite applications of biochar. The reactors employed were hydrothermal, fixed-bed batch vertical and fixed-bed batch horizontal-tube reactors. The vertical and tube reactors, at the same temperature, produced biochars having comparable elemental carbon content, surface functionalities, thermal degradation pattern and peak

heat release rates. The hydrothermal reactor, although, a low-temperature process, produced biochar with high fire resistance because the formed tarry volatiles sealed water inside the pores, which hindered combustion.

Liu et al., (2021): Nitrate is one of the most common water contaminants and has caused severe environmental problems. This work aimed to investigate the effects of integration of denitrifier with biochars on nitrate removal and understand the underlying mechanisms. The results showed that physiochemical properties of biochars varied according to different feedstocks, which influenced bacteria attachment and nitrate removal through adsorption. However, bacteria could colonize on biochars no matter biochars surface were favourable for bacteria attachment or not. Immobilization of denitrifier on biochars significantly improved nitrate removal efficiencies and reduced lag time.

Nakhli et al., (2021): In this work, several methods are described for preparing repacked biochar-amended soils. It deals with the pre-column packing, determination of optimum moisture content and bulk density of biochar-amended soils. The modifications are rinsing and oven-drying biochar, determining the optimum moisture content to achieve a homogenous mixture, determining the desired bulk density before column packing, and mixing and packing under wet conditions.

Antunes et al., (2022): In this study, researchers investigate on the phosphorous removal, by using algae biochar. A potential circular economy approach for microalgae was investigated considering the crucial stages of bio refinery. Important stages, such as drying of biomass, production of biochar (pyrolysis), and application of biochar for phosphorus removal were studied and reported. The physicochemical properties of biomass as well as biochar were characterized and were correlated with their capacity to adsorb phosphorus (P).

Wang et al., (2022): This work investigates on the impact of the biochar microstructure on the hydraulic conductivity of sand-biochar mixtures. It experimentally investigated the hydraulic properties of sand-biochar mixtures for uniformly graded sand. This approach enables to statically evaluate the interparticle porosity and tortuosity of biochar. The researchers showed that by excluding biochar's intraparticle porosity, the hydraulic conductivity prediction accuracy can be significantly improved, thus providing a more accurate prediction of the hydraulic behaviour of the soil-biochar filters.

2.3 LITERATURE GAP

Although several studies have investigated the removal efficiency of biochar in various applications, there is a significant literature gap regarding its effectiveness in the removal of heavy metals and chemical compounds from contaminated water sources. While some research has touched upon this topic, existing studies predominantly focus on organic pollutants or agricultural applications of biochar. Limited attention has been given to assessing the potential of biochar as an efficient and sustainable adsorbent for heavy metal removal, particularly in industrial wastewater treatment scenarios. Therefore, this project aims to fill this literature gap by investigating the removal efficiency of coconut shell biochar in the context of nitrate and phosphate contaminated water.

CHAPTER 3

METHODOLOGY

3.1 GENERAL

The methodology for biochar treatment in wastewater can be summarized into several key steps. They are biochar preparation, preparation of synthetic water sample, conduction of iodine value test, conduction of batch and column methods of treatment, evaluation and analysis of results at various parameters.

3.2 BIOCHAR PREPARATION

Coconut shell biochar is a type of biochar derived from coconut shells, which are a waste product of the coconut industry. The preparation of coconut shell biochar involves several steps. They are collection and preparation of coconut shells, carbonization, heating and pyrolysis, cooling and quenching, crushing and sizing and storage.

3.3 PREPARATION OF SYNTHETIC WATER SAMPLE

Synthetic water samples containing nitrates and phosphates are laboratory-prepared solutions used for experimental purposes to simulate the presence of these contaminants in water. In the laboratory, synthetic water samples containing nitrates and phosphates are used for various purposes, including studying the behaviour and treatment of these contaminants, assessing the effectiveness of treatment technologies, conducting adsorption experiments.

3.4 CONDUCTION OF IODINE VALUE TEST

The iodine value test is a common method used to determine the efficiency of biochar in adsorbing organic compounds. Specifically, it measures the amount of iodine in milligrams that can be adsorbed by a certain weight of biochar material. The iodine value test provides an indication of the surface area and porosity of the biochar, as well as its potential for adsorbing organic pollutants. It is important to note that the test results should be interpreted in conjunction with other characterization and performance tests to fully assess the effectiveness of the biochar for specific applications.

3.5 CONDUCTION OF BATCH EXPERIMENT

Batch tests were performed to find out the maximum capacity of adsorbent. For conducting batch experiment 200ml of sample is to be taken in a beaker in which 4 gm and 8gm of biochar is to be added in to the beaker and putting on to the magnetic stirrer and stirring is started at 150 and 300 revolutions per minutes respectively. 50 ml of sample is to be drawn in time interval of 30, 60, 90 and 120 minutes from this beaker. Then filtered on Whatman filter paper and the filtrate is analyzed in spectrophotometer for respective concentration. At the end of 2hr the stirring is stopped and the experiment is terminated.

3.6 CONDUCTION OF COLUMN EXPERIMENT

Column tests were then to be performed to provide a real-life treatment process but on a smaller scale. Continuous experiment were carried out in glass column having 7.5 cm length and 5 cm diameter, in which adsorbent was filled in the column and at the top and bottom filter beds are placed for the supporting purpose. Effluent sample was feed from top and the sample was collected from the bottom. The experiment were carried out by changing the bed height of adsorbent as 0.5 cm, 1 cm, 1.5 cm, 2 cm and 2.5 cm for coconut shell biochar, powdered activated charcoal and granular activated charcoal.

3.7 EVALUATION AND ANALYSIS OF RESULT

The analysis of the respective concentration of filtrate effluent sample is done by using UV-Visible Double Beam Spectrophotometer.

CHAPTER 4

BIOCHAR

4.1 GENERAL

Biochar is the lightweight black residue, made of carbon and ashes, remaining after the pyrolysis of biomass. Biochar is defined by the International Biochar Initiative as "the solid material obtained from the thermochemical conversion of biomass in an oxygen-limited environment". Biochar is a stable solid that is rich in pyrogenic carbon. Biochar can be produced from almost as many types of feedstock as there are types of biomass including: agricultural wastes, rice husks, bagasse, paper products, animal manures, and even urban green waste.

4.2 COCONUT SHELL BIOCHAR

Coconut shell biochar refers to a type of charcoal-like substance that is produced from coconut shells through a process called pyrolysis. Pyrolysis involves heating the coconut shells in the absence of oxygen, which leads to the decomposition of organic material and the production of biochar. Coconut shell biochar is known for its high carbon content, porous structure, and stable composition. In environmental remediation, coconut shell biochar is utilized for its adsorption properties. It can effectively remove pollutants, heavy metals, and organic contaminants from water and soil. Its porous structure provides a large surface area for adsorption, making it an environmentally friendly and cost-effective solution for water and soil treatment. The CSBC is shown in fig.4.1.

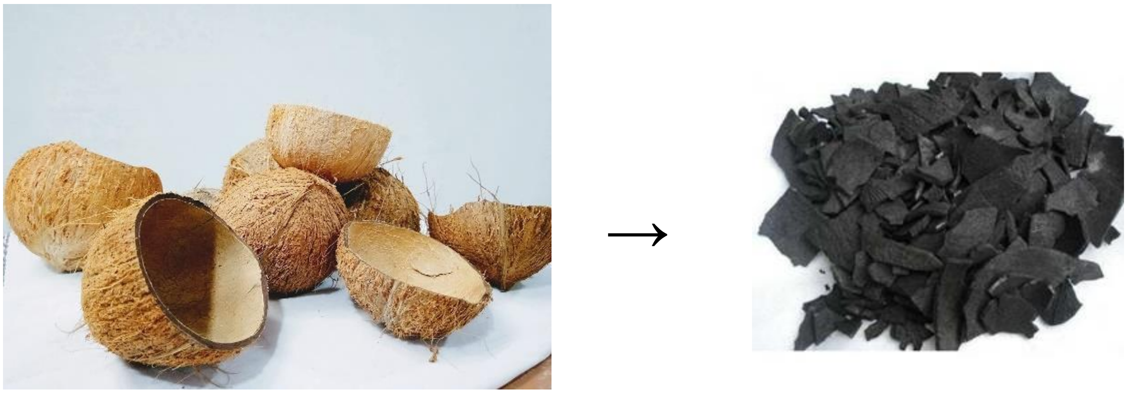


Fig. 4.1 Coconut shell biochar (Caballero et al. 2020)

CHAPTER 5

BET ANALYSIS

5.1 GENERAL

Brunauer-Emmett-Teller (BET) surface area analysis is the multi-point measurement of an analyte's specific surface area (m2/g) through gas adsorption analysis, where an inert gas such as nitrogen is continuously flowed over a solid sample, or the solid sample is suspended in a defined gaseous volume.

5.2 BET MEASUREMENT

BET analysis requires measurement of an adsorption isotherm. Because the BET model uses the relative pressure of the adsorptive, it is necessary that the gas be condensable at the adsorption temperature or the gas is really a vapour.
The measurement involves:

- Putting a known amount of sample into a sample cell or container.
- Outgassing or other treatment of the sample, to remove impurities and moisture.
- Increasing the pressure of the gas, while measuring the amount adsorbed on the surface of the sample. For the best precision, this is done at a number of discrete pressures, and with a wait for equilibrium and measurement of the amount adsorbed at each point.
- The saturation vapour pressure is measured at the same time, or it may be calculated from knowledge of the temperature.
- BET is most widely performed using adsorption of Nitrogen gas at 77 K, the boiling point of liquid nitrogen, but other species and temperatures are also used such as Argon at 87 K (liquid Argon temperature), Krypton at 77 K, Carbon dioxide at 0 °C or at 25 °C, etc.

5.3 BET ANALYSIS RESULTS

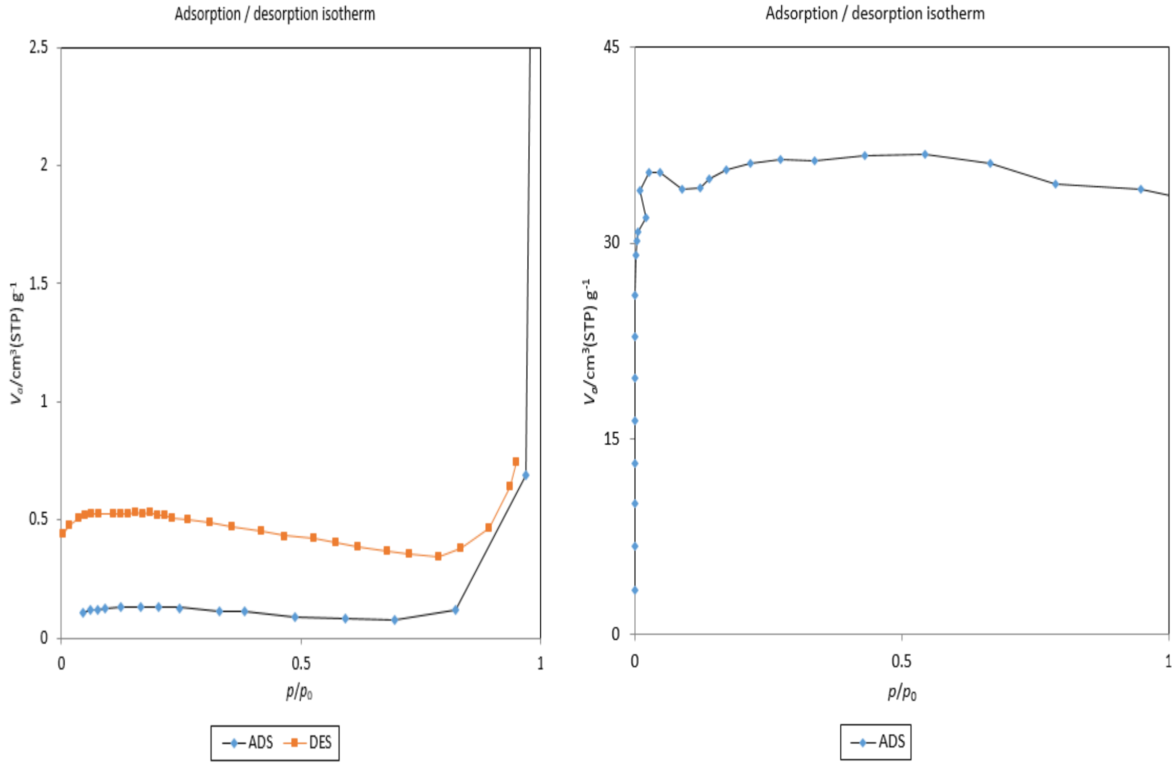
5.3.1 General

The BET (Brunauer-Emmett-Teller) Surface Area Analysis were conducted for coconut shell biochars pyrolyzed at 700^{0}C and 445^{0}C from Central Sophisticated Instrumentation Facility (CSIF), University of Calicut. The analysis was performed using adsorption of Nitrogen gas at adsorption temperature of 77 K.

5.3.2 Adsorption/desorption isotherm

A plot of relative pressure verses volume adsorbed obtained by measuring the amount of an inert gaseous or liquid substance (sorbent, usually H2 or N2) which adsorbs onto the surface of interest (sorbate), and the subsequent amount that desorbs at a constant temperature. That is, relative pressure 'p/p_0'(where, 'p' is the partial vapour pressure of adsorbate gas in equilibrium with the surface and 'p_0' is the saturated pressure of adsorbate gas) in X-axis and volume adsorbed 'V_a' in Y-axis.

The obtained adsorption/desorption isotherm for coconut shell biochars pyrolyzed at 445^{0}C and 700^{0}C are shown in fig.5.1.

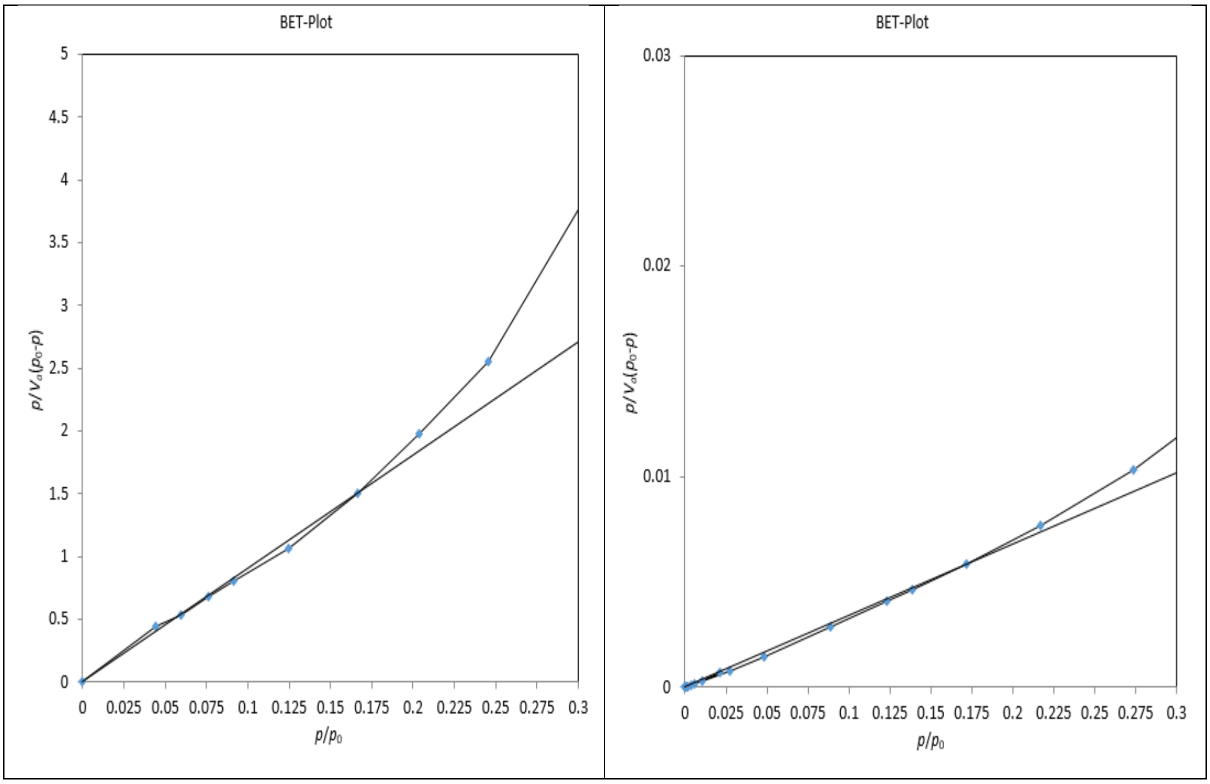


(a) (b)

Fig.5.1 Adsorption/desorption isotherm of CSBC 445^{0}C (a) and CSBC 700^{0}C (b)

5.3.3 BET Plot

A plot of (p/Va (p_0 - p)) against (p/p_0), is called the BET plot, where 'p' is the partial vapour pressure of adsorbate gas in equilibrium with the surface, 'p_0' is the saturated pressure of adsorbate gas and 'Va' is the volume adsorbed. The obtained BET plot for coconut shell biochars pyrolyzed at 445^{0}C and 700^{0}C are shown in fig.5.2.



(a) (b)

Fig.5.2 BET plot of CSBC 445^{0}C (a) and CSBC 700^{0}C (b)

The obtained results of the biochars after the BET plot are given in table 5.1.

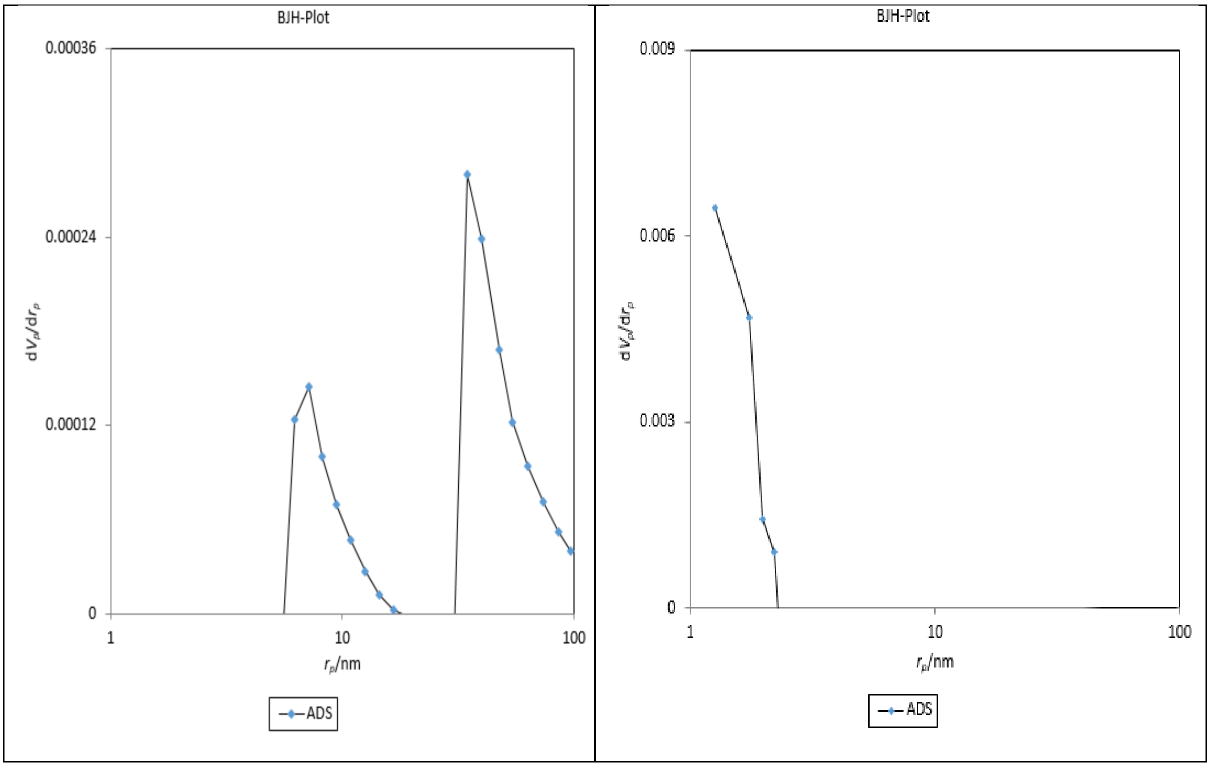
Table 5.1. BET plot results

Parameters	Coconut Shell Biochar- 445^{0}C	Coconut Shell Biochar- 700^{0}C
Surface area, m^2/g	0.48234	128.3
Vm, monomolecular adsorption volume, cm^3/g	0.1108	29.477
Total pore volume, cm^3/g	0.0079141	0.052196
Mean pore diameter, nm	65.631	1.6273

From the result we can understand that the 700^{0}C pyrolyzed CSBC has more surface area than 445^{0}C CSBC.

5.3.4 BJH Plot

BJH is a method to determine pore size distribution. The graph is obtained by percentage change of pore volume (*ΔV$_p$/ Δr$_p$*) against micropore radius (*r$_p$*). The obtained BJH plot for coconut shell biochars pyrolyzed at 445^{0}C and 700^{0}C are shown in fig.5.3. The results obtained from the BJH method are given in table 5.2.



(a) (b)

Fig.5.3 BJH plot of CSBC 445^{0}C (a) and CSBC 700^{0}C (b)

Table 5.2 BJH method results

Parameters	Coconut Shell Biochar-445^{0}C	Coconut Shell Biochar-700^{0}C
Pore volume,V$_p$, cm^3/g	0.0076571	-0.00052113
Pore radius, r$_p$, nm	34.75	1.26
Surface area of pore, a$_p$, m^2/g	-0.08798	5.8781

CHAPTER 6

PREPARATION OF BIOCHAR

6.1 GENERAL

The common thermochemical techniques used for biochar production include pyrolysis, hydrothermal carbonization, gasification, flash carbonization and torrefaction. Of all these methods, pyrolysis is the most commonly used to produce biochar.

6.2 SLOW PYROLISIS

Slow pyrolysis is the method used when char is the primary product. The general method is running the process between 400 to 800 °C and has a heating rate under 10 °C per minute. The feedstock used in the process is of larger particle size, several methods can use large pieces of wood if the feeding system can handle it. To optimize the production of char vapour is kept in the process for a longer duration of time. These technologies have been known and used for a long time. New industrial processes for slow pyrolysis is producing both char and can collect the other products or use them for heat and power production. The bio-oil can also contain valuable chemicals such as acetone, methanol and acetic acids. A slow pyrolysis process can have several stages for separation of the products created in the process. In general, a slow pyrolysis process produces char and gas, some parts of the product gas can be condensed into liquid fractions. The amount is these product is affected by the type of feedstock and process set up. Depending on market demand for the various products the process should be developed to maximize profit for the situation.

6.3 PROCEDURE FOR PREPARATION OF BIOCHAR

The physical and chemical properties of biochar depend primarily on the types of feedstock and pyrolysis conditions i.e., temperature, residence time, reactor type and heating rate. The biochar has a great potential for sorption from aqueous solutions

6.3.1 Selection of Feedstock:

Any organic material can be used as a feedstock for making biochar, such as wood chips, coconut shells, or water hyacinth. Choose a feedstock that is readily available in our area and that will produce a high-quality biochar.

6.3.2 Drying:

Once the feedstock is selected, it needs to be dried to remove the moisture content. This is done by spreading the material out in the sun or by using a drying machine.

6.3.3 Preparation of Feedstock:

If the feedstock is in large pieces, it may need to be chipped or shredded into smaller pieces that are suitable for pyrolysis.

6.3.4 Load the Pyrolysis Chamber:

The pyrolysis chamber can be any container that can withstand high temperatures, such as a carbonizer. The schematic diagram of carbonizer is shown in fig.6.1. Fill the carbonizer with the prepared feedstock, leaving enough space for air to circulate around the material.

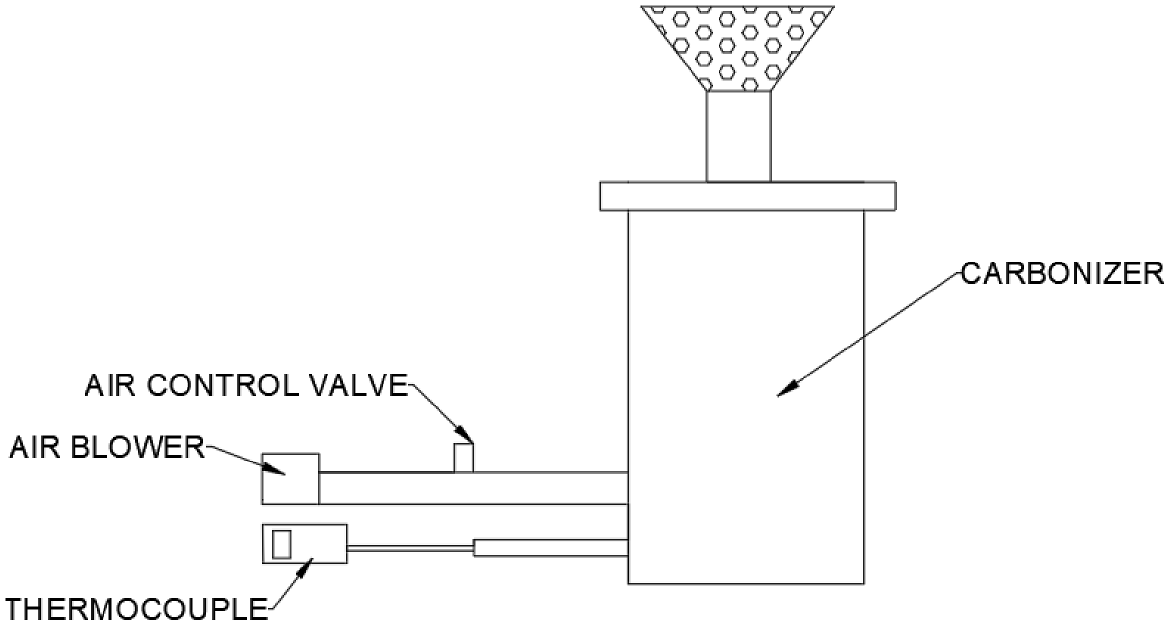


Fig.6.1 Schematic diagram of carbonizer

6.3.5 Heat the Chamber:

Start a fire at the bottom of the chamber to heat the feedstock. The fire should be hot enough to pyrolyze the feedstock, but not so hot that it burns it completely to ash. Cover the chamber

to limit the amount of oxygen that enters and allow the pyrolysis process to take place. Fig. 6.2 shows the various stages of preparation of biochar.

Fig 6.2 Preparation of biochar

6.3.6 Monitor the Process:

The pyrolysis process can take several hours to complete, depending on the size of the feedstock and the temperature of the fire. Monitor the process to ensure that the biochar is not overcooked or undercooked. When the process is complete, the biochar should be dark in colour and have a light, porous texture.

6.3.7 Cool and Store the Biochar:

Once the pyrolysis process is complete, allow the biochar to cool before removing it from the chamber. Store the biochar in a dry place to prevent it from absorbing moisture and losing its effectiveness.

6.4 BIOCHARS PREPARED

For a maximum yield of biochar, the technique chosen for production must be appropriate depending on the biomass type and also the process conditions such as heating rate, temperature, residence time, etc. must be optimum. These conditions are crucial since they may affect the physical and chemical states of biochar during the production process. The biochars prepared on various temperature and residence time are shown in the table 6.1.

Table 6.1: Biochars prepared

BIOCHAR TYPE	TEMPERATURE (ºC)	DURATION	DATE
COCONUT SHELL BIOCHAR	502.8	1 hr 22 min	15/11/2022
	809.3	2 hrs 16 min	23/11/2022
	700	1hr 40 min	22/12/2022
	445	2 hrs 23 min	22/12/2022
	716	2 hrs 22 min	25/12/2022
	700	2 hrs 7 min	26/12/2022
	700	1 hr 39 min	26/12/2022
	700	1 hr 27 min	27/12/2022
	702	1 hr 24 min	28/12/2022
	700	1 hr 38 min	28/12/2022
	700	2 hrs 10 min	28/12/2022
	800	1 hr 35 min	29/12/2022

CHAPTER 7

IODINE VALUE TEST FOR BIOCHAR

7.1 GENERAL

American standard test method (ASTM D4607-94, 2006) was used to determination of iodine number of activated carbon. The amount of iodine absorbed [mg/g (carbon)] at residual iodine concentration of 0.02N is reported as iodine number. The Iodine number test is commonly used method to measure the surface area of biochar. This test is based on the principle that iodine is absorbed by the surface of the biochar, and the amount of iodine absorbed is proportional to the surface area of the biochar. The iodine number is a relative indicator of porosity in an activated carbon. It does not necessarily provide a measure of the carbon's ability to absorb other species. This test method is based upon a three-point adsorption isotherm.

7.2 MATERIALS REQUIRED

These are the various materials required for the iodine value test:

- Analytical balance
- Biochar sample
- Erlenmeyer flask
- Desiccator
- Burette
- Conical flask
- Pipette
- Whatman filter paper
- Funnel

7.3 REAGENTS

The various reagents used for the iodine value test are listed below:

- Hydrochloric acid (HCl): Dilute 70ml conc. HCl to 550ml distilled water.
- Sodium thiosulphate ($Na_2S_2O_3$) solution (0.1N): Add 24.82g $Na_2S_2O_3$ to 75ml distilled water. Add 0.1g Na_2CO_3 to it and dilute to 1L.

- Standard Iodine solution (0.1N): Weigh 12.7g iodine and 19.1g KI, mix it with 2 to 5ml distilled water and dilute it to 1L.
- Potassium Iodate solution (0.1N): Add 100 ml distilled water to 3.5667g KIO_3 and dilute it to 1L.
- Starch solution

7.4 PROCEDURE

- Weighted the three biochar dosages of individual temperature (W_1, W_2, W_3 grams) using electronic balance.
- Each weighted sample of carbon was transferred to a clean, dry 250cm³ Erlenmeyer flask equipped with a ground glass stopper.
- 10ml of HCl solution is added to each flask containing carbon. Each flask is stopped and swirled gently until the carbon is completely wetted.
- The stoppers are loosened to vent the flasks and they are heated to bring the contents to boil for 30 sec. The flasks are removed and cooled in room temperature (29ºC).

Fig. 7.1 Titration

- 100ml of 0.1N iodine solutions are pipetted in to each flask. The addition of iodine solution to the three flasks are staggered to minimize delay in handling.
- The flask is immediately stoppard and shaken vigorously for 30seconds. Each mixture is quickly filtered by gravity through one sheet of folded Whatman filter paper.
- Clean beakers are used to collect the filtrates. Each filtrate is swirled and 50ml of it is pipetted in to clean 250cm³ Erlenmeyer flask.

- Each filtrate is titrated with 0.1N sodium thiosulphate solutions until the solution turned yellow as shown in fig.7.1.
- 2ml of freshly prepared starch indicator solution is added and the titration continued with sodium thiosulphate until one drop produced a colourless solution.
- The volume of sodium thiosulphate used is noted.

7.5 EQUATION

Two calculations are required for each carbon dosage, as X/M and C.

Iodine absorbed (X/M) per gram of carbon (mg/g) is calculated as follows:

$$\frac{X}{M} = \frac{[A - (DF)(B)(S)]}{M} \qquad \rightarrow \quad (1)$$

Where,

A= (N_2) iodine (12693.0)

N_2=Iodine (N) = 0.1

S=Sodium thiosulphate (cm^3)

M=Carbon used (g)

DF=Dilution factor= (100+10)/50=2.2

B= (N1) (126.93)

N_1=Sodium thiosulphate (N) = 0.1

The residual filtrate (C) is calculated as follows:

$$C = \frac{N1 * S}{F} \qquad \rightarrow \quad (2)$$

Where,

N_1 = Sodium thiosulphate (N) = 0.1

F = Filtrate, mL

S = Sodium thiosulphate, mL

Carbon dosage can be estimated as follows:

$$M = \frac{[A - (DF)(C)(126.93)(50)]}{E} \qquad \rightarrow \quad (3)$$

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Where,

M= Carbon, gm

A= $(N_2)(12693.0)$

DF= Dilution factor

C= Residual iodine

E= Estimated iodine number of carbon

Three carbon dosages are calculated using three values of C (usually 0.01, 0.02 and 0.03).

7.6 IODINE VALUE TEST 1

The below tables show the observations, calculations, result and inference of the iodine value test conducted for coconut shell biochar.

7.6.1 Observations

The observed values of iodine value test titrations carried out in Set 1 (75µ passing) and Set 2 (75µ retained) are tabulated in table 7.1.

Table 7.1: Observation of titrations

Set No.	Trial No.	Weight of biochar (g)	Volume of biochar (ml)	Burette reading of $Na_2S_2O_3.5H_2O$ (ml)			Volume of $Na_2S_2O_3.5H_2O$ consumed (ml)
				Initial reading (ml)	Intermediate reading (ml)	Final reading (ml)	
1	1	1.450	50	0	36.8	39.7	39.7
	2	1.980	50	0	27.4	28.7	28.7
	3	2.259	50	0	30.8	32.3	32.3
2	4	1.700	50	0	40.2	41.7	41.7
	5	1.980	50	0	40.8	43.1	43.1
	6	2.259	50	0	40.2	41.6	41.6

7.6.2 Calculations

The tables 7.2 and 7.3 shows the calculations for X/M and C values, using equations (1), (2) and (3).

Table 7.2: Calculations for the y axis of the graph

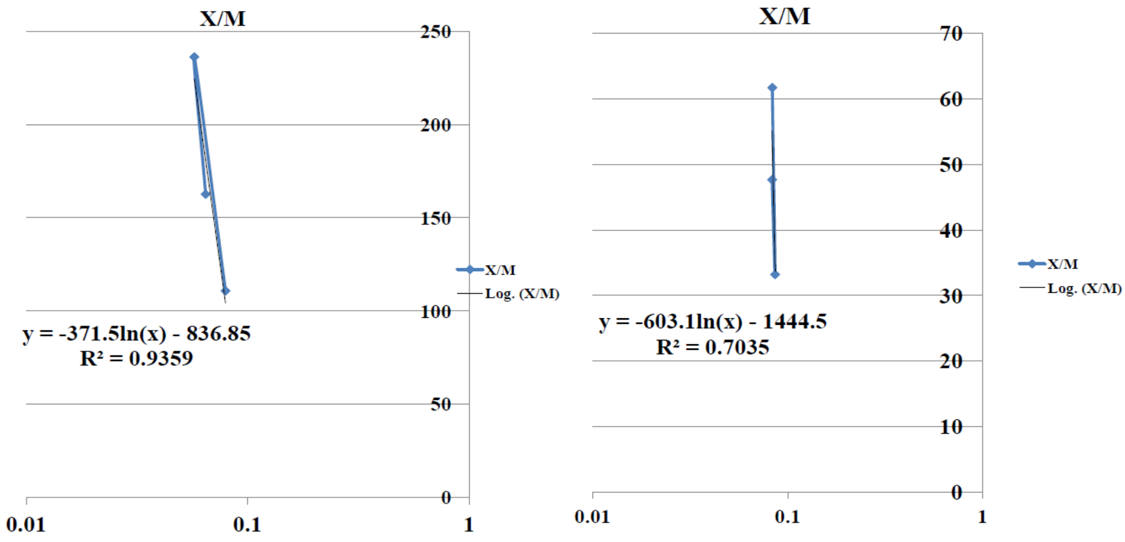
X/M								
	N1	N2	A	DF	B	S	M	X/M
1	0.1	0.1	1269.3	2.2	12.693	39.7	1.45	110.82300
	0.1	0.1	1269.3	2.2	12.693	28.7	1.98	236.29490
	0.1	0.1	1269.3	2.2	12.693	32.3	2.259	162.60970
2	0.1	0.1	1269.3	2.2	12.693	41.7	1.7	61.67305
	0.1	0.1	1269.3	2.2	12.693	43.1	1.98	33.20694
	0.1	0.1	1269.3	2.2	12.693	41.6	2.259	47.64792

Table 7.3: Calculations for the x axis of graph

Set No.	C			
	N1	S	F	C
1	0.1	39.7	50	0.0794
	0.1	28.7	50	0.0574
	0.1	32.3	50	0.0646
2	0.1	41.7	50	0.0834
	0.1	43.1	50	0.0862
	0.1	41.6	50	0.0832

7.6.3 Graphical Representation

The graph shown in fig.7.2 is the graphical representation for iodine value test. It is obtained by plotting X/M (as shown in table 7.2) on X-axis and C (as shown in table 7.3) on Y-axis.



Set 1 Set 2

Fig.7.2 Graphical representation for the iodine test 1

7.6.4 Results from Graph

Iodine Value of Biochar;

- Set 1

  R^2=0.9359

  y=-371.5 ln(x)-836.85=-371.5 ln(0.02)-836.85=616.46

- Set 2

  R^2=0.7035

  y=-603.1ln(x)-1444.5=-603.1 ln(0.02)-1444.5=914.841

  Where, R^2 is the regression coefficient

7.6.5 Inference

Based on the obtained iodine value of the coconut shell biochar, it can be inferred that the biochar possesses a relatively high degree of unsaturation. This suggests that the biochar may have significant potential as an absorbent material for capturing and removing pollutants.

7.7 IODINE VALUE TEST 2

The below tables show the observations, calculations, result and inference of the iodine value test conducted for coconut shell biochar.

7.7.1 Observations

The observed values of iodine value test titrations carried out in Set 1, 2 and 3 (425µ passing) are tabulated in table 7.4.

Table 7.4: Observation of titrations

Set No.	Trial No.	Weight of biochar (g)	Volume of biochar (ml)	Burette reading of $Na_2S_2O_3.5H_2O$ (ml)			Volume of $Na_2S_2O_3.5H_2O$ consumed (ml)
				Initial reading (ml)	Intermediate reading (ml)	Final reading (ml)	
1	1	5.6690	50	0	30.7	31.6	31.6
	2	6.6003	50	0	21.6	22.8	22.8
	3	7.5310	50	0	30.8	31.8	31.8
2	4	4.2520	50	0	33.9	34.6	34.6
	5	4.9500	50	0	30.4	31.4	31.4
	6	5.6480	50	0	28	29	29
3	7	2.8340	50	0	29.1	30	30
	8	3.3001	50	0	29.5	30.6	30.6
	9	3.7650	50	0	30.4	30.8	30.8

7.7.2 Calculations

The tables 7.5 and 7.6 shows the calculations for X/M and C values, using equations (1), (2) and (3).

Table 7.5: Calculations for the y axis of graph

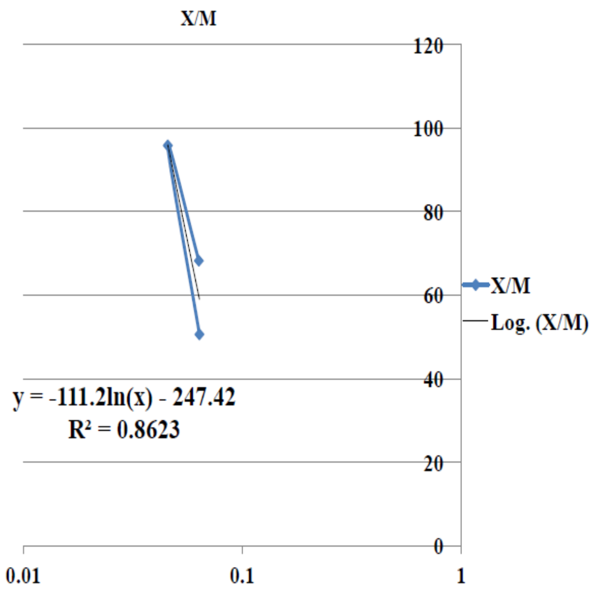
X/M								
	N1	N2	A	DF	B	S	M	X/M
1	0.1	0.1	1269.3	2.2	12.693	31.6	5.6690	68.24531
	0.1	0.1	1269.3	2.2	12.693	22.8	6.6003	95.84703
	0.1	0.1	1269.3	2.2	12.693	31.8	7.5310	50.63042
2	0.1	0.1	1269.3	2.2	12.693	34.6	4.2520	71.28618
	0.1	0.1	1269.3	2.2	12.693	31.4	4.9500	79.28638
	0.1	0.1	1269.3	2.2	12.693	29	5.6480	81.35386
	0.1	0.1	1269.3	2.2	12.693	30	2.8340	152.2802
	0.1	0.1	1269.3	2.2	12.693	30.6	3.3001	125.6954
	0.1	0.1	1269.3	2.2	12.693	30.8	3.7650	108.6912

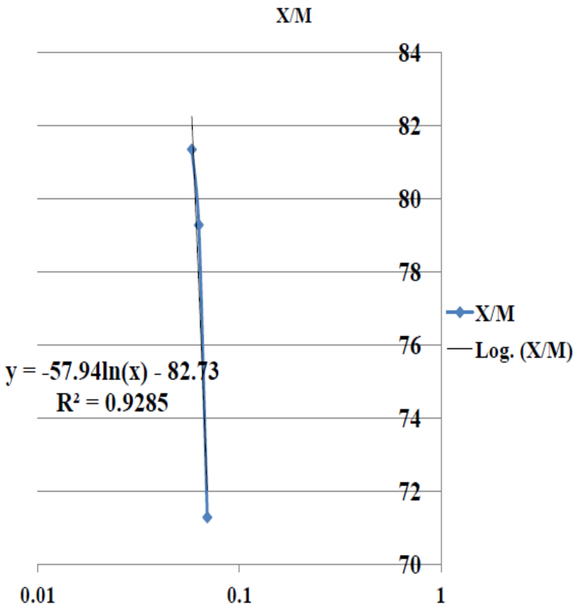
Table 7.6: Calculations for the x axis of graph

C				
	N1	S	F	C
1	0.1	31.6	50	0.0632
	0.1	22.8	50	0.0456
	0.1	31.8	50	0.0636
2	0.1	34.6	50	0.0692
	0.1	31.4	50	0.0628
	0.1	29	50	0.0580
3	0.1	30	50	0.0600
	0.1	30.6	50	0.0612
	0.1	30.8	50	0.0616

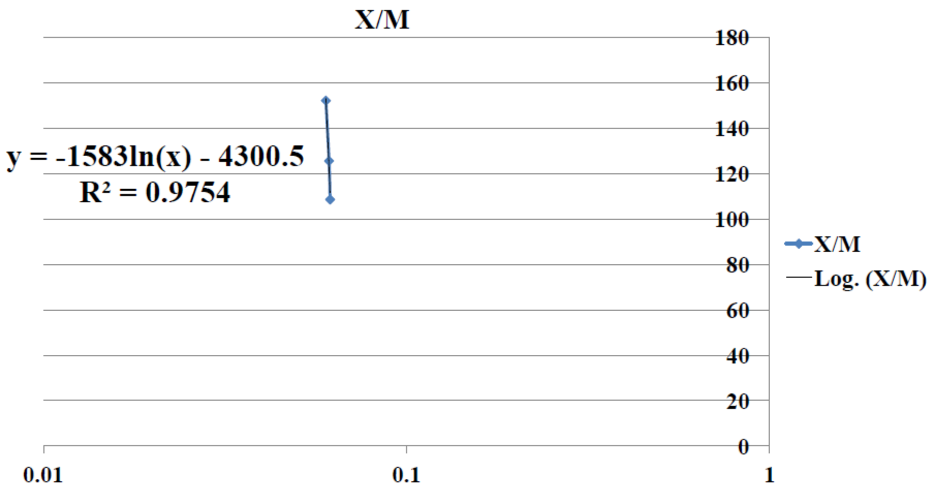
7.7.3 Graphical Representation

The graph shown in fig.7.3 is the graphical representation for iodine value test. It is obtained by plotting X/M (as shown in table 7.5) on X-axis and C (as shown in table 7.6) on Y-axis.





Set 1 Set 2



Set 3

Fig.7.3 Graphical representation for the iodine test 2

7.7.4 Results from Graph

Iodine Value of Biochar

- SET 1

  R^2=0.8623

  y=-111.2ln(x)-247.42=-111.2 ln(0.02)-247.42=187.5969

- SET 2

  R^2=0.9285

  y=-57.94ln(x)-82.73=-57.94 ln(0.02)-82.73=143.9326

- SET 3

  R^2=0.9754

  y=-1583ln(x)-4300.5=-1583 ln(0.02)-4300.5=1892.232

7.7.5 Inference

The iodine value exhibited by the CSBC indicates a lower degree of carbonaceous surface adsorption sites. Hence, this BC shows a reduced capacity for adsorbing contaminants. Therefore the CSBC may have limited effectiveness in applications requiring high adsorption or filtration capabilities.

CHAPTER 8

PREPARATION OF SYNTHETIC SAMPLE

8.1 GENERAL

Effluent samples can vary significantly in composition and quality depending on the source and time of sampling. By preparing synthetic water samples, specific contaminants and their concentrations can be precisely controlled, allowing for consistent and repeatable testing and treatment evaluations. This control is essential for research, development, and optimization of treatment processes.

8.2 PREPARATION OF SYNTHETIC PHOSPHATE WATER

8.2.1 General

Synthetic phosphate water is a solution containing inorganic phosphate salts and is commonly used in biological and chemical research. Here's how you can prepare synthetic phosphate water:

8.2.2 Materials

Sodium phosphate monobasic (NaH_2PO_4)

Sodium phosphate dibasic (Na_2HPO_4)

Distilled or deionized water

Graduated cylinder or volumetric flask

Stirring rod

8.2.3 Procedure

- Calculate the desired concentration of phosphate in the solution. For example, if you want to prepare a 0.1 M solution of phosphate, you will need to dissolve 1g of Na_2HPO_4 and 1g of NaH_2PO_4 in 1 litre of water.
- Weigh out the required amount of NaH_2PO_4 and Na_2HPO_4 using a balance and transfer them into a clean, dry glass beaker.
- Add a small amount of water (about 100 mL) to the beaker and stir the mixture with a stirring rod until the salts are completely dissolved.

- Transfer the solution to a graduated cylinder or volumetric flask, and add enough water to make up the final volume. For example, if you want to prepare 1 litre of solution, add water to the 1 litre mark.
- Stir the solution thoroughly to ensure that the salts are evenly distributed.

8.3 PREPARATION OF SYNTHETIC NITRATE WATER

8.3.1 General

It is not recommended to intentionally prepare synthetic nitrate-containing water as nitrates can have harmful effects on human health in high concentrations. However, if you need to prepare a nitrate-containing solution for laboratory purposes, here are the steps:

8.3.2 Materials

Distilled water
Potassium nitrate (KNO_3)
Measuring cylinder or beaker
Stirring rod

8.3.3 Procedure

- Measure the required volume of distilled water using a measuring cylinder or beaker.
- Weigh the appropriate amount of potassium nitrate (KNO_3) needed to achieve the desired concentration.
- Add the KNO_3 to the distilled water and stir using a stirring rod until it dissolves completely.
- Measure the concentration of the nitrate-containing water.

CHAPTER 9

BATCH AND COLUMN EXPERIMENTS

9.1 BATCH EXPERIMENT

9.1.1 General

Batch experiments, also known as static systems, are carried out by adding certain amount of solid into solution containing specific concentration of contaminants with a specific solid/liquid (S/L) ratio. These mixtures are vigorously stirred or shaken during the entire reaction time. The concentration of contaminant in solution is monitored and its change is thus regarded as the amount of contaminant to be partitioned onto solid. The merit of the batch approach lies in that it does not require much space of experiment apparatus while all variables of interest could be obtained experimentally. A batch adsorption method using biochar is a common approach for wastewater treatment. In this method, biochar is added to a batch of wastewater and allowed to interact with the contaminants present in the water. The biochar acts as an adsorbent, binding the contaminants onto its surface through various physical and chemical interactions. The effectiveness of a batch adsorption method using biochar can be influenced by several factors, including biochar properties, wastewater characteristics, contact time, agitation, and other operational parameters.

9.1.2 Apparatus Required

The following are the various apparatus required for the batch experiment.

- Magnetic stirrer
- Magnetic Beads
- Beakers
- Weighing machine
- Filter papers
- Funnel
- Conical flask
- China dish

9.1.3 Procedure

- Take synthetic water sample in a beaker.
- Add suitable different proportions (4gm, 8gm) of biochar to the beaker.
- Keep the beaker with the magnetic beads on a magnetic stirrer and fix 150 and 300 revolutions per minute for each proportions.
- Take small amount of sample at 30, 60, 90 and 120 minutes.
- Filter the sample on a filter paper and analyse the results.
- Stop the stirrer after 2 hours. The conduction of the experiment is shown in figure 9.1.

Fig.9.1 Conduction of batch experiments at 150 and 300 rpm

9.1.4 Result

i) Nitrate Batch Test

The obtained results of the batch experiment to check the nitrate removal efficiency of coconut shell biochars, powdered activated charcoal and granular activated charcoal are shown here.

1. Coconut Shell Biochar, 700°C at 2hrs 7mins

The graphical representation of the removal efficiency of the biochar at various proportions and at different revolutions per minute are shown in fig.9.2.

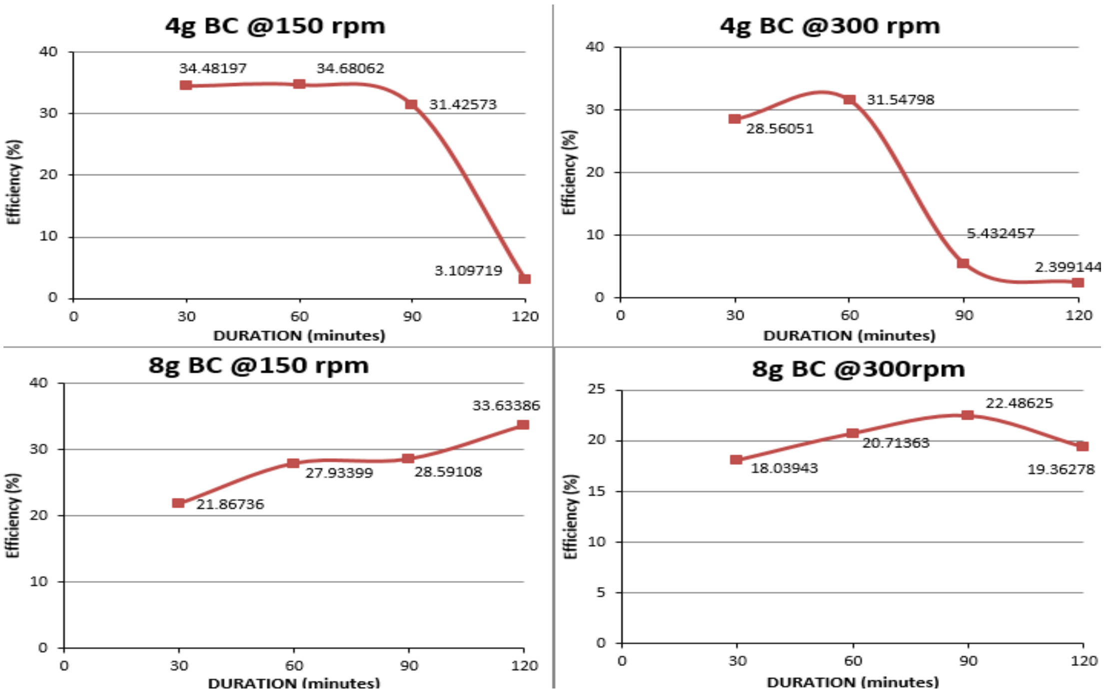


Fig.9.2 Duration v/s efficiency graphs of 700^{0}C CSBC on nitrate removal

2. Coconut Shell Biochar, 445°C at 2hrs 23mins

The graphical representation of the removal efficiency of the biochar at various proportions and at different revolutions per minute are shown in fig.9.3.

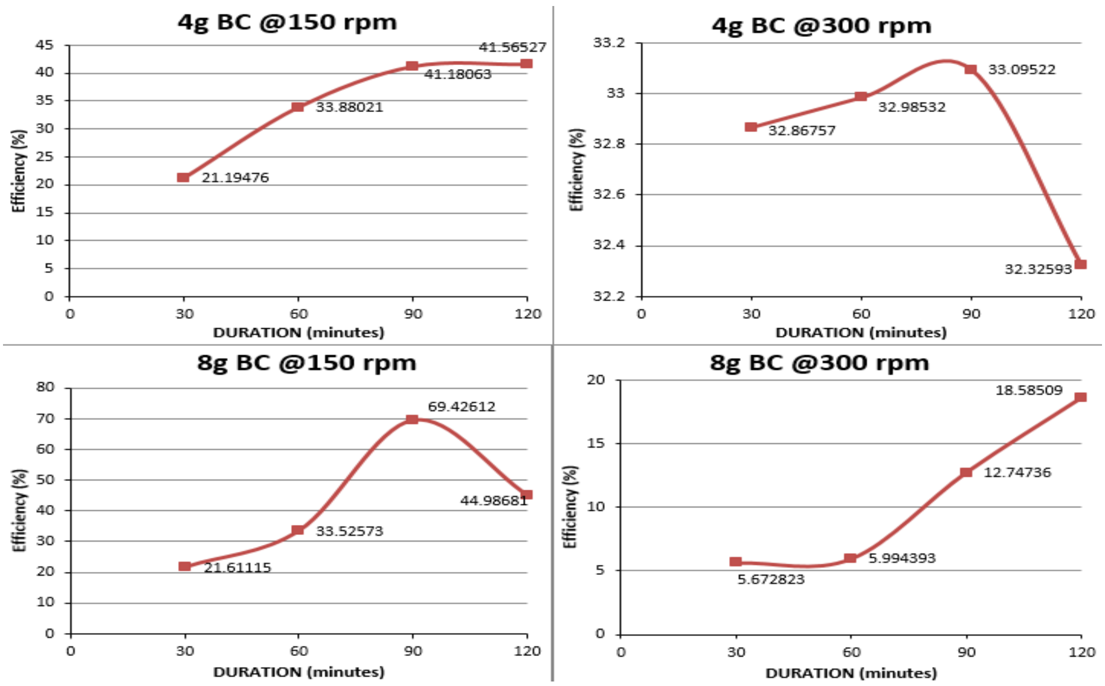


Fig.9.3 Duration v/s efficiency graphs of 445^{0}C CSBC on nitrate removal

3. Powdered activated charcoal

The graphical representation of the removal efficiency of the biochar at various proportions and at different revolutions per minute are shown in fig.9.4.

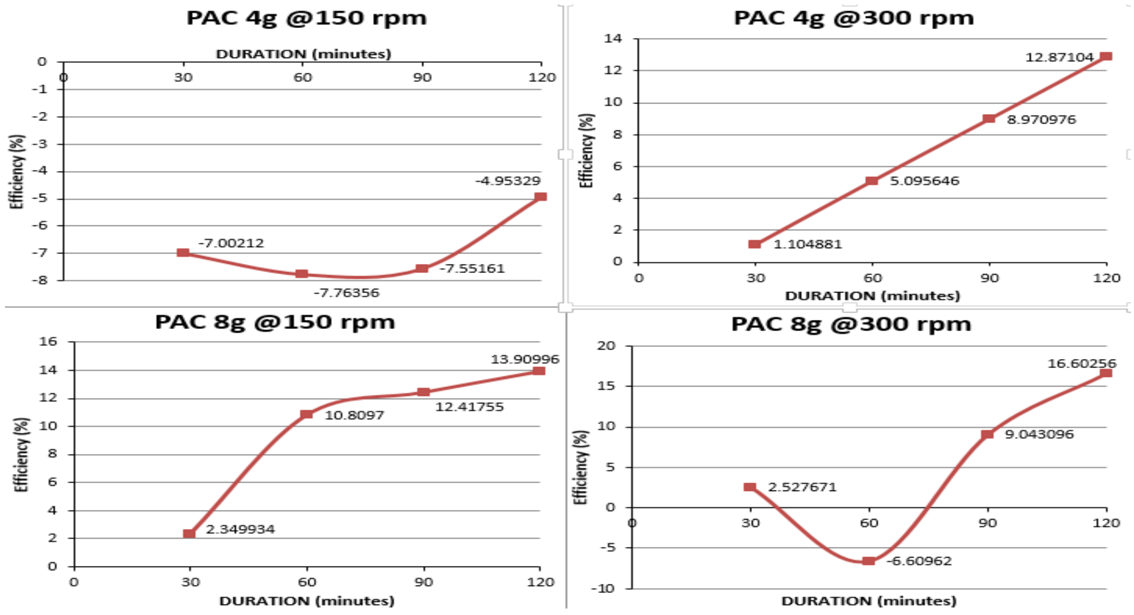


Fig.9.4 Duration v/s efficiency graphs of PAC on nitrate removal

4. Granular activated charcoal

The graphical representation of the removal efficiency of the biochar at various proportions and at different revolutions per minute are shown in fig.9.5.

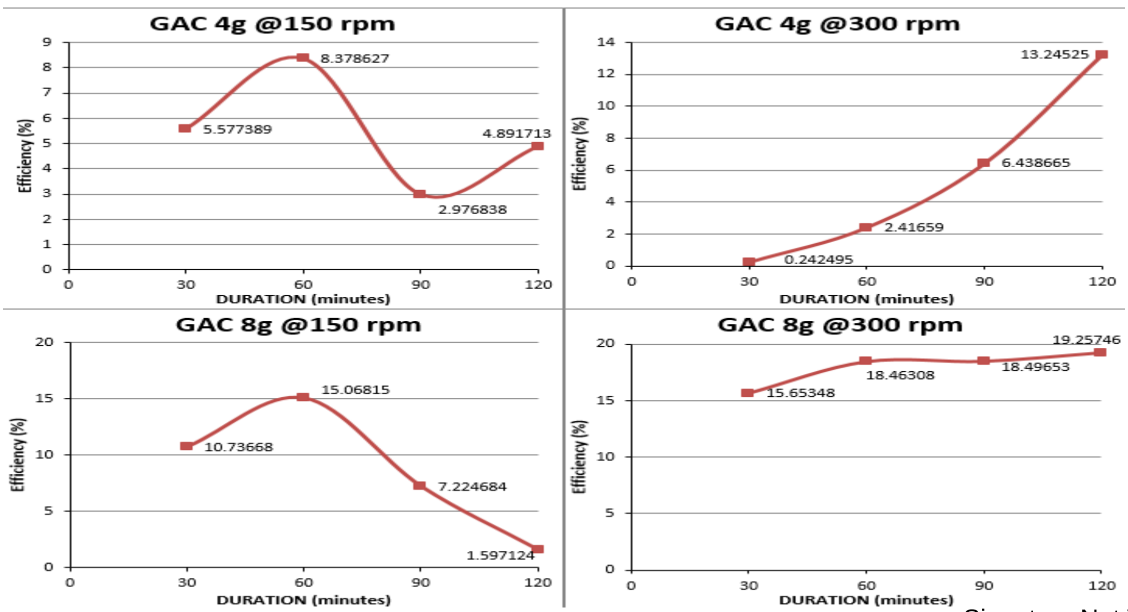


Fig.9.5 Duration v/s efficiency graphs of GAC on nitrate removal

9.1.5 Combination of Parameters

i) Duration v/s Efficiency

The comparison of duration v/s efficiency graph for the nitrate removal using various sorbents are given in fig. 9.6. The sorbents are 700^{0}C CSBC, 445^{0}C CSBC, PAC and GAC. The values at various revolutions per minute, contact periods and biochar dosages are compared here.

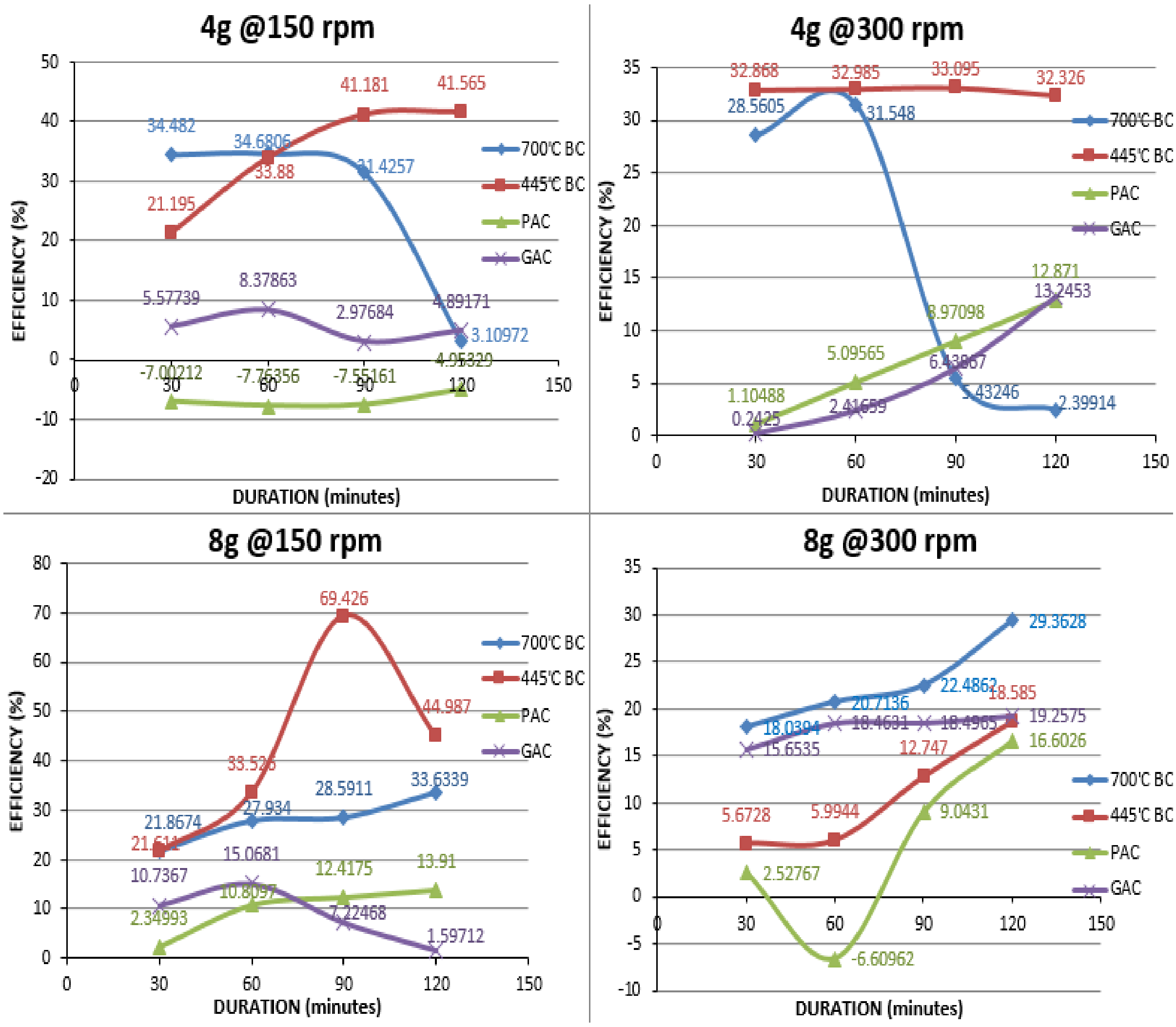


Fig.9.6 Duration v/s efficiency graphs of various sorbents for nitrate removal

ii) Duration v/s Change in pH

The comparison of duration v/s change in pH graph for the nitrate removal using various sorbents are given in fig. 9.7. The sorbents are 700^{0}C CSBC, 445^{0}C CSBC, PAC and GAC. The values at various revolutions per minute, contact periods and biochar dosages are compared here.

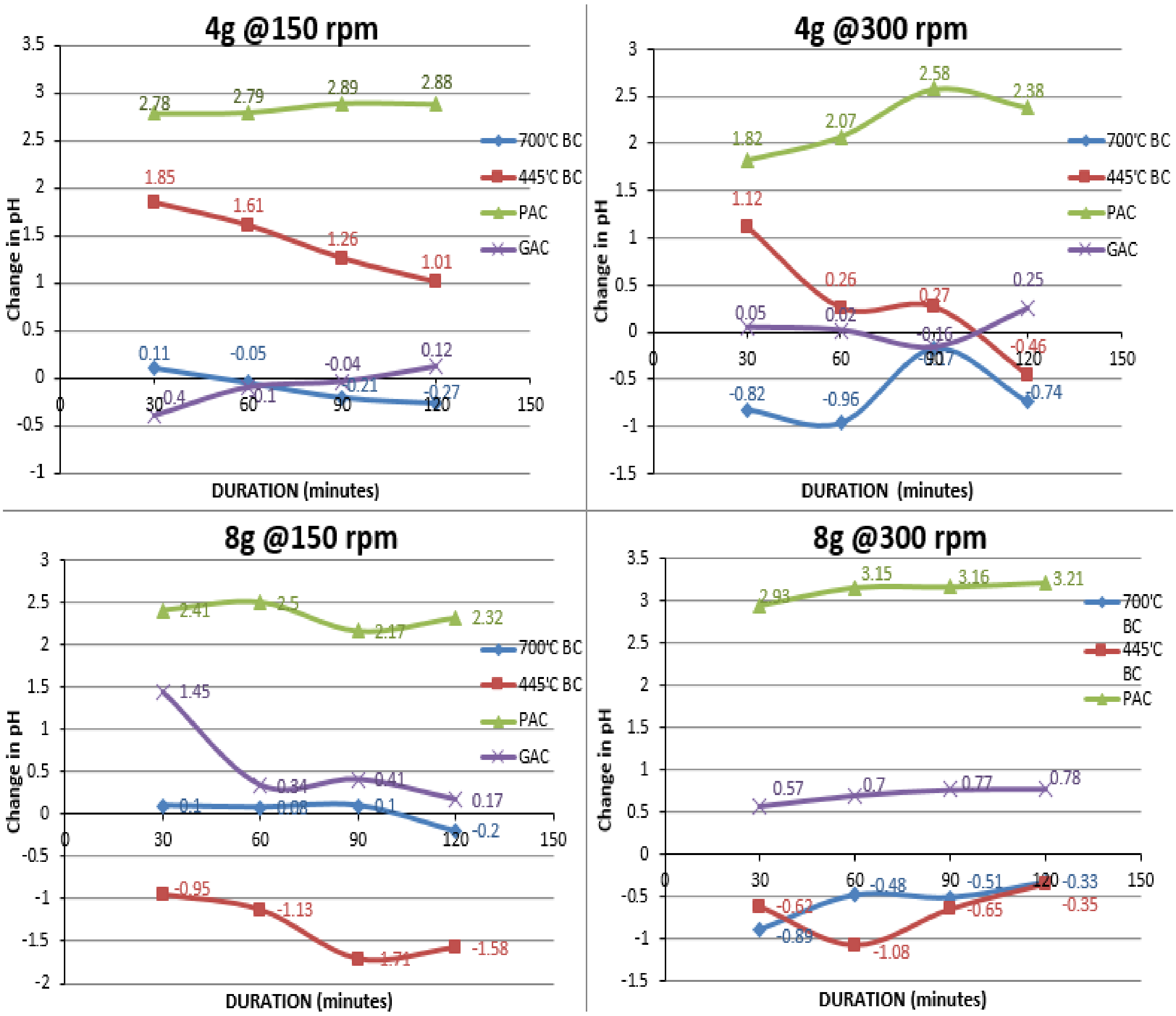


Fig.9.7 Duration v/s change in pH graphs of various sorbents for nitrate removal

9.1.6 Analysis of the Result

i) Effect of Dosage

Biochar has a porous structure that provides a large surface area for adsorption, allowing it to bind to pollutants such as heavy metals and chemical compounds. The results shows that higher dosages can result in greater adsorption capacity and improved removal rates.

ii) Effect of Contact Time

The contact time plays a crucial role in the effectiveness of the adsorption process and significantly affect the treatment efficiency. Initially, the adsorption rate is high as there are more available adsorption sites. Over time, the rate slows down as the concentration of the

adsorbate decreases in the wastewater. The adsorption process follows a typical pattern, starting with a rapid adsorption phase followed by a slower equilibrium phase.

iii) Effect of Revolutions per Minute

The number of revolutions influences the overall contaminant removal efficiency. Higher revolutions generate more turbulence and maintain the biochar particles in suspension, preventing settling or aggregation. Thus ensured a uniform contact between the biochar and the wastewater, enhancing adsorption efficiency. The biochar tends to settle quickly at 150 rpm, increasing the agitation to 300 rpm improved the overall effectiveness.

iv) Effect of pH

At lower pH levels, the biochar's surface becomes protonated, resulting in an increased positive charge. This enhanced positive charge can facilitate the electrostatic attraction between the biochar and the negatively charged nitrate ions, promoting adsorption. Therefore, the batch adsorption method using coconut shell biochar is expected to show higher nitrate removal efficiency at lower pH levels.

Conversely, at higher pH levels, the surface of the biochar becomes deprotonated, resulting in a decreased positive charge or even a negative charge. This change in surface charge reduces the electrostatic attraction between the biochar and the nitrate ions, potentially leading to a decrease in adsorption efficiency. Therefore, the batch adsorption method using coconut shell biochar may exhibit lower nitrate removal efficiency at higher pH levels.

The synthetic water treated with PAC and GAC shows high variation from initial pH, whereas much variations where not observed for synthetic water treated with CSBCs.

9.2 COLUMN EXPERIMENT

9.2.1 General

In chemistry, Column chromatography is a technique which is used to separate a single chemical compound from a mixture dissolved in a fluid. Column chromatography separates substances based on differential adsorption of compounds to the adsorbent as the compounds move through the column at different rates which allows them to get separated in fractions. This technique can be used on a small scale as well as large scale to purify materials that can

be used in future experiments. This method is a type of adsorption chromatography technique. Column absorption treatment using biochar offers a sustainable and cost-effective approach for removing various pollutants from water or liquid streams. Its versatility, combined with the renewable nature of biochar, makes it an attractive option for water treatment applications and environmental remediation.

9.2.2 Apparatus Required

- Glass column
- Mobile phase
- Stationary phase
- Filter paper
- Glass filter
- Sorbent
- Beakers
- Funnel
- Tray

9.2.3 Procedure

- Take a clean glass column.
- Keep the fine filter and the Whatman filter paper at the bottom of the glass column.
- Fill sorbents (700^0 C coconut shell biochar, 445^0C coconut shell biochar, powdered activated charcoal and granular activated charcoal) in the column at various bed heights of 0.5cm, 1cm, 1.5cm, 2cm and 2.5cm for different trials.
- Fill the top of the column with Whatman filter paper and a perforated glass filter.
- Feed the effluent sample from the top of the glass column and collect the effluent sample from the bottom. The schematic diagram and the conduction of column experiment are shown in fig.9.8.
- Collect the samples of each set of experiment and store it in a small volumetric flasks.
- The sample is undergone for tests for various parameters like pH and Chemical Oxygen Demand (COD).
- Determine the concentration of the effluent using UV-Visible Double Beam Spectrophotometer.

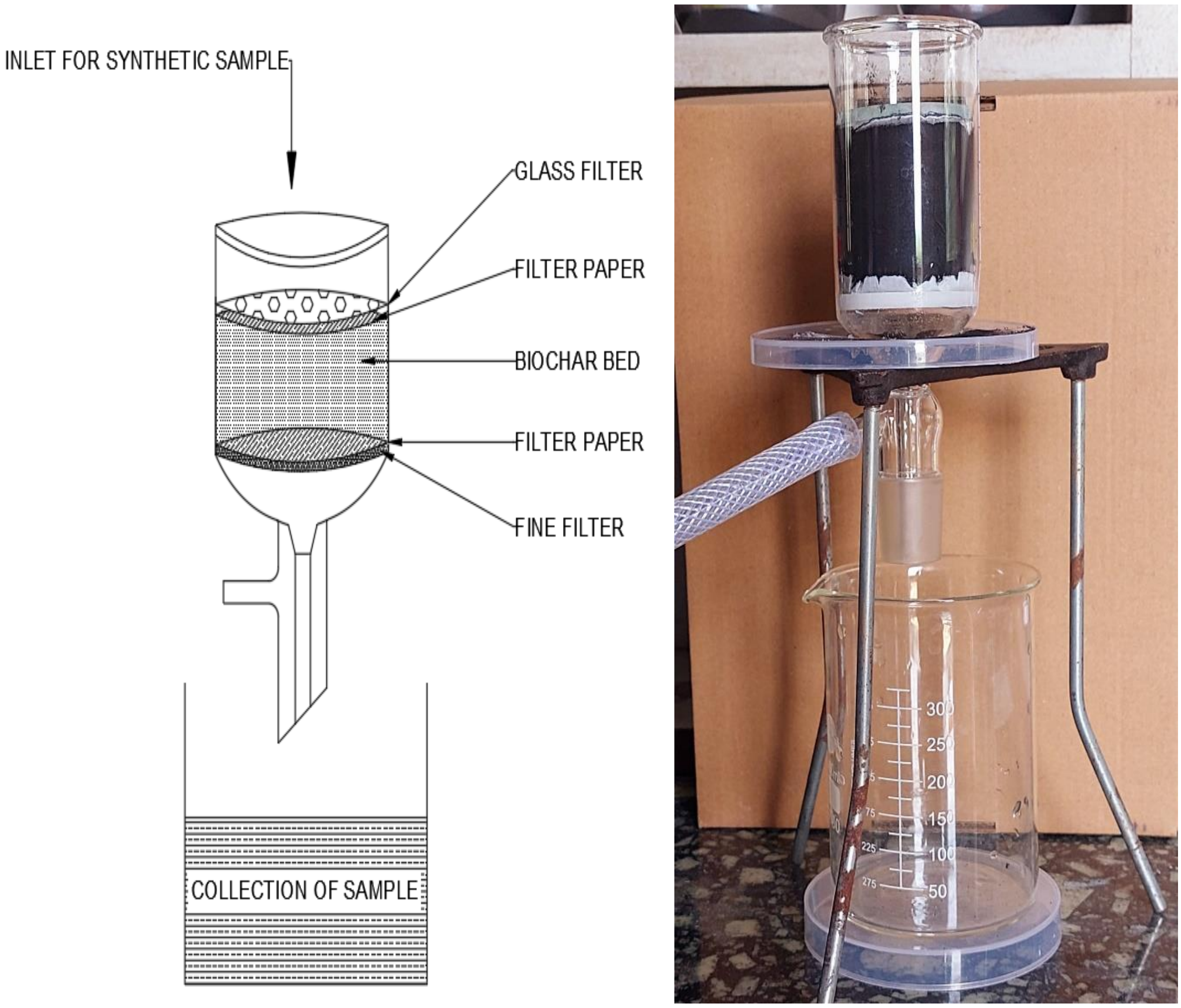


Fig. 9.8 Schematic diagram and conduction of column test

9.2.4 Result

i) Nitrate column experiment

The obtained results of the column experiment to check the nitrate removal efficiency of coconut shell biochars, powdered activated charcoal and granular activated charcoal are shown in figures.

1. Coconut Shell Biochar, 700°C at 2hrs 7mins

CSBC pyrolyzed at 700^0C were used to remove nitrate from the synthetic sample and various results were obtained. Fig.9.9 shows the bed height v/s concentration graph for nitrate removal using 700^0 C CSBC. Fig.9.10 shows the bed height v/s pH graph, bed height v/s efficiency graph is given in fig.9.11 and bed height v/s COD graph is shown in fig.9.12.

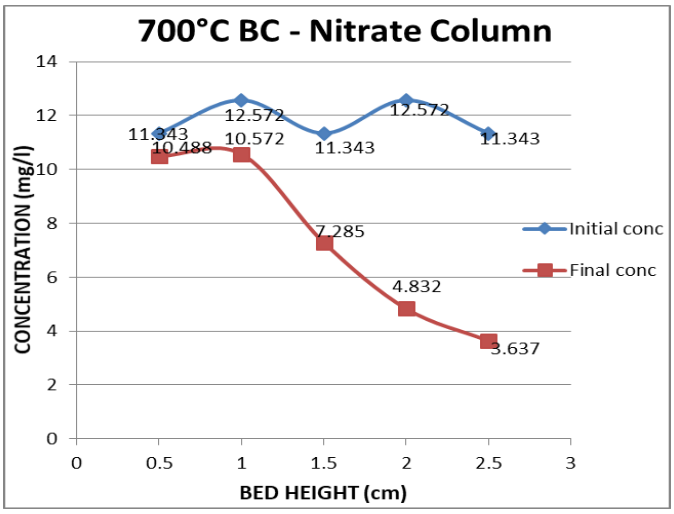


Fig.9.9 Bed height v/s concentration graph for nitrate removal using 700^0 C CSBC

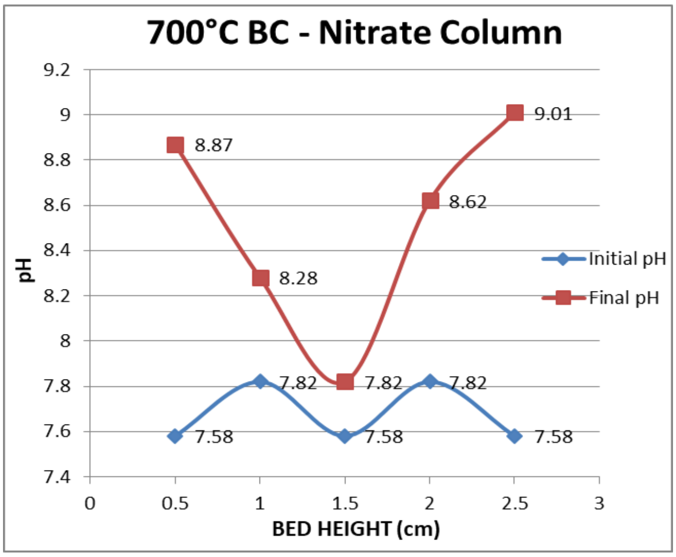


Fig.9.10 Bed height v/s pH graph for nitrate removal using 700^0C CSBC

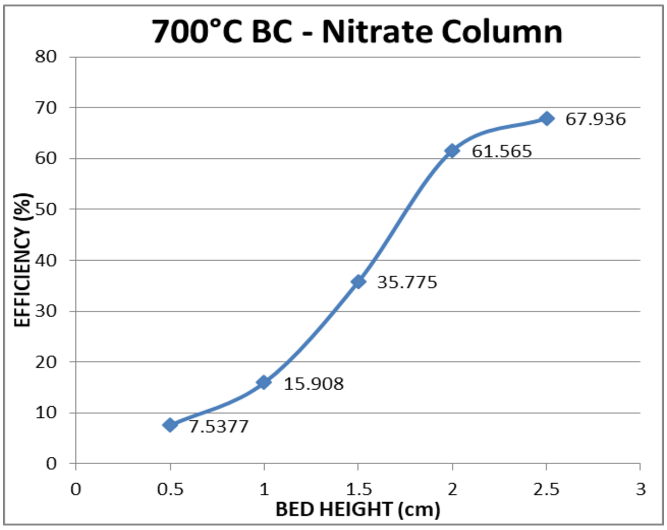


Fig.9.11 Bed height v/s efficiency graph for nitrate removal using 700^0C CSBC

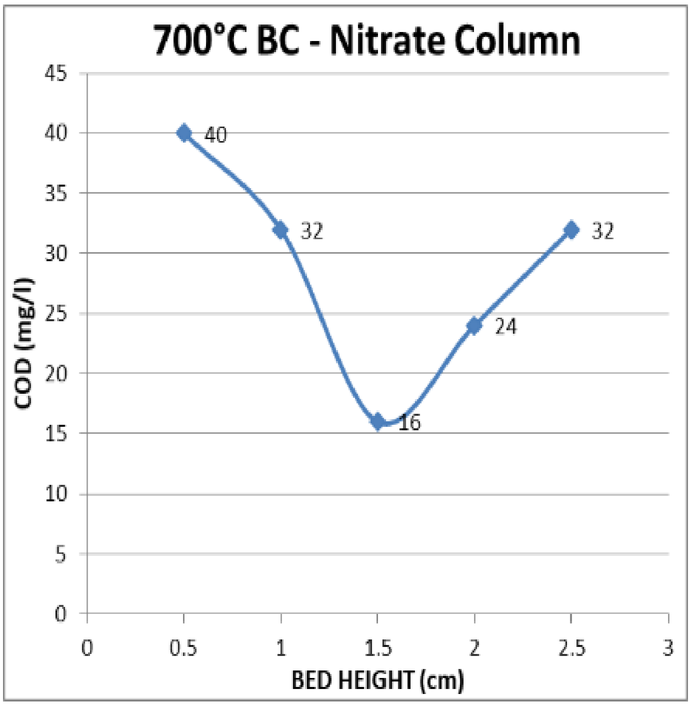


Fig.9.12 Bed height v/s COD graph for nitrate removal using 700^{0}C CSBC

2. Coconut Shell Biochar, 445°C at 2hrs 7mins

CSBC pyrolyzed at 445^{0}C were used to remove nitrate from the synthetic sample and various results were obtained. Fig.9.13 shows the bed height v/s concentration graph. Fig.9.14 shows the bed height v/s pH graph and bed height v/s efficiency graph is given in fig.9.15.

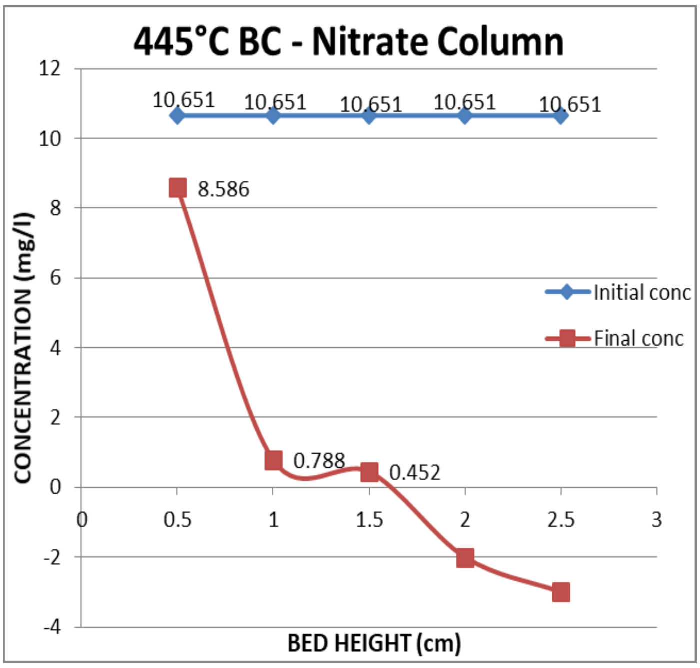


Fig.9.13 Bed height v/s concentration graph for nitrate removal using 445^{0}C CSBC

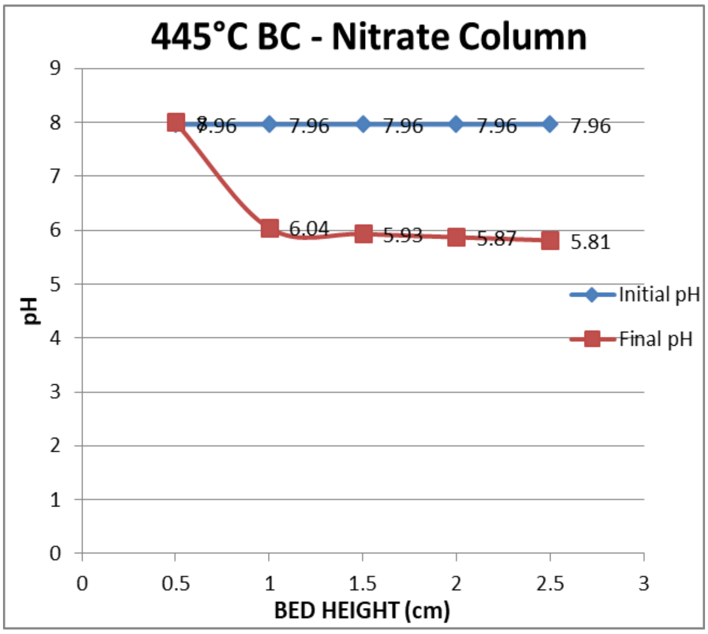


Fig.9.14 Bed height v/s pH graph for nitrate removal using 445^{0}C CSBC

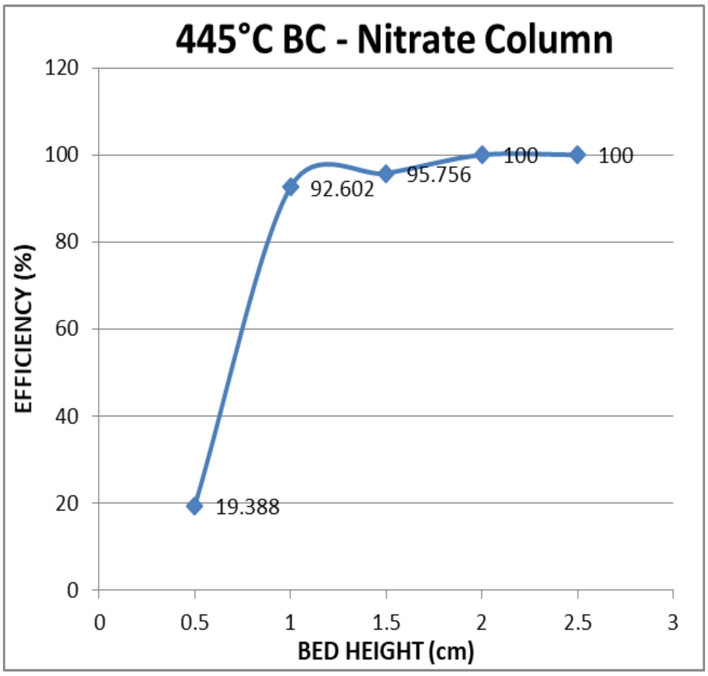


Fig.9.15 Bed height v/s efficiency graph for nitrate removal using 445^{0}C CSBC

3. Powdered activated charcoal

Powdered activated charcoal were used to remove nitrate from the synthetic sample and various results were obtained. Fig.9.16 shows the bed height v/s concentration graph. Fig.9.17 shows the bed height v/s pH graph, bed height v/s efficiency graph is given in fig.9.18 and bed height v/s COD graph is shown in fig.9.19.

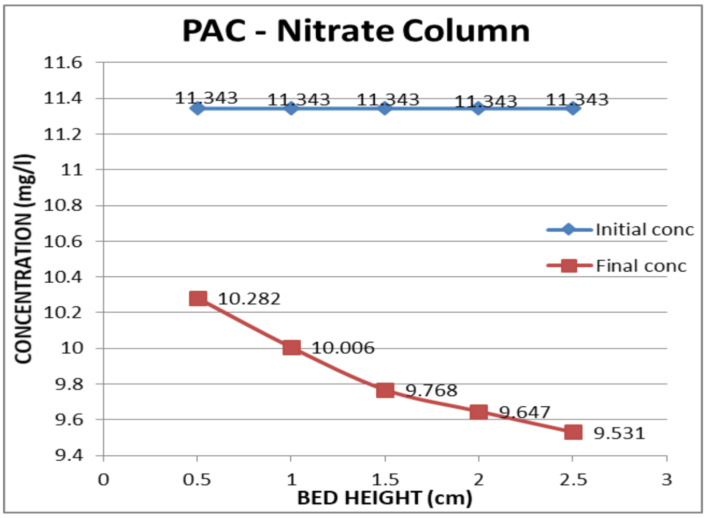


Fig.9.16 Bed height v/s concentration graph for nitrate removal using PAC

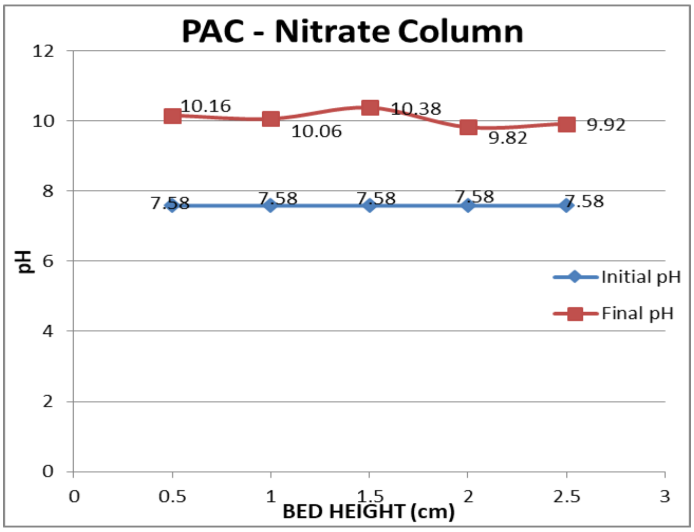


Fig.9.17 Bed height v/s pH graph for nitrate removal using PAC

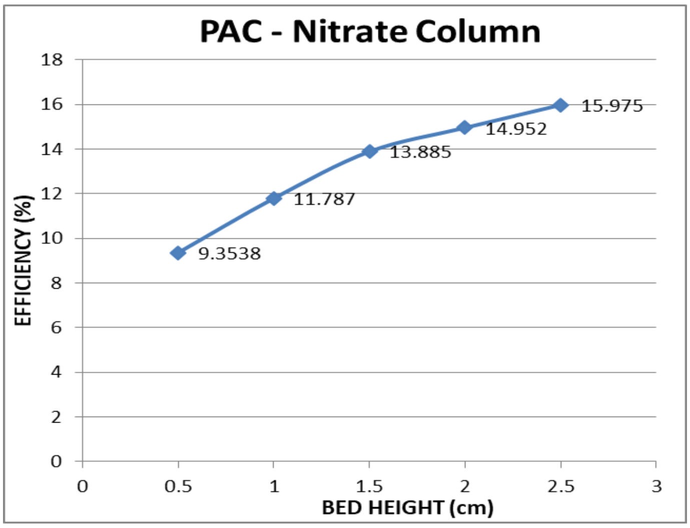


Fig.9.18 Bed height v/s efficiency graph for nitrate removal using PAC

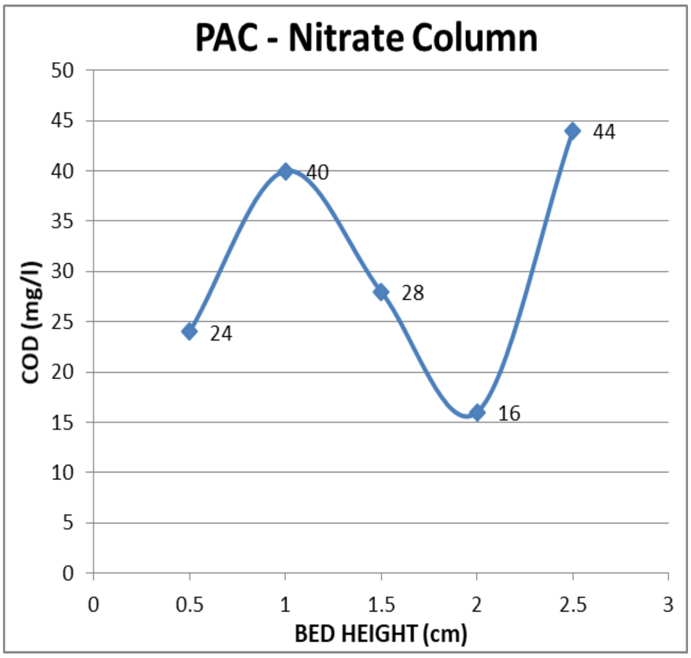


Fig.9.19 Bed height v/s COD graph for nitrate removal using PAC

4. Granular activated charcoal

Granular activated charcoal were used to remove nitrate from the synthetic sample and various results were obtained. Fig.9.20 shows the bed height v/s concentration graph. Fig.9.21 shows the bed height v/s pH graph and bed height v/s efficiency graph is given in fig.9.22.

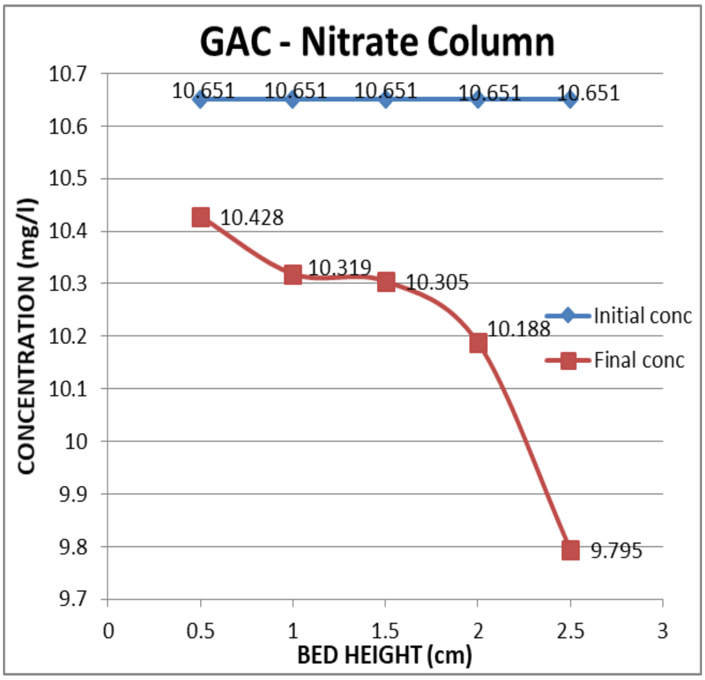


Fig.9.20 Bed height v/s concentration graph for nitrate removal using GAC

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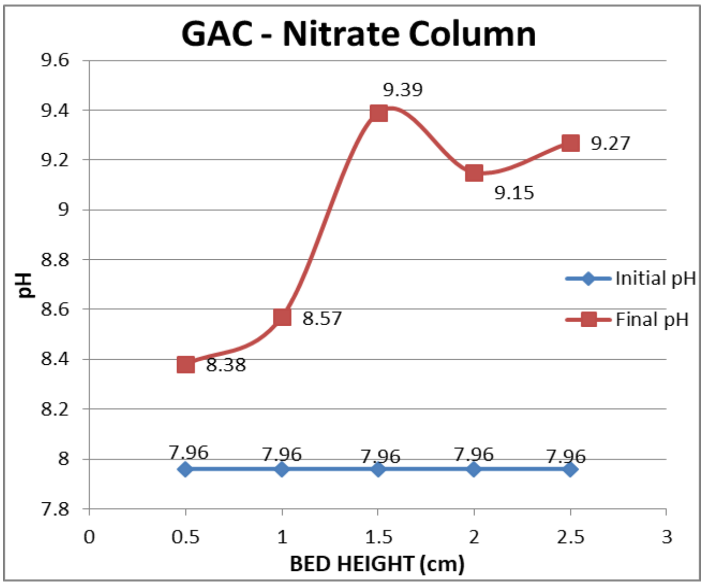

Fig.9.21 Bed height v/s pH graph for nitrate removal using GAC

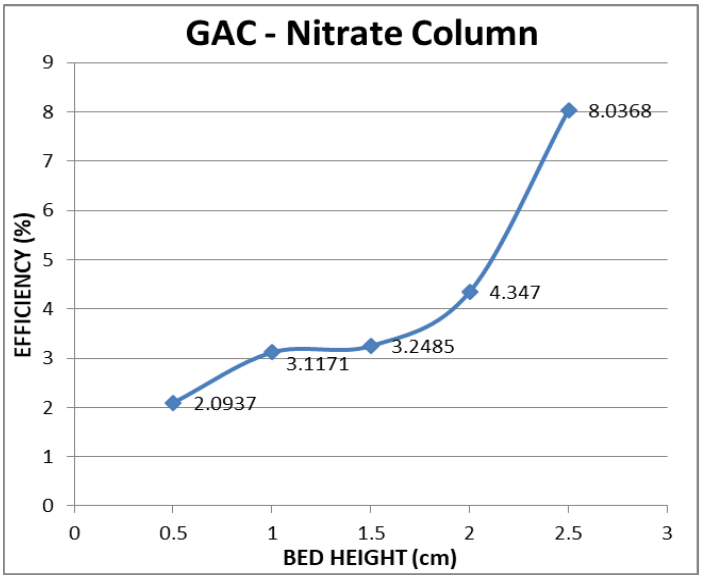

Fig.9.22 Bed height v/s efficiency graph for nitrate removal using GAC

ii) Phosphate Column Experiment

The obtained results of the column experiment to check the phosphate removal efficiency of coconut shell biochars, powdered activated charcoal carbon and granular activated charcoal are shown in figures.

1. Coconut Shell Biochar, 700°C at 2hrs 23mins

CSBC pyrolyzed at 700^{0}C were used to remove phosphate from the synthetic sample and various results were obtained. Fig.9.23 shows the bed height v/s concentration graph. Fig.9.24 shows the bed height v/s pH graph and bed height v/s efficiency graph is given in fig.

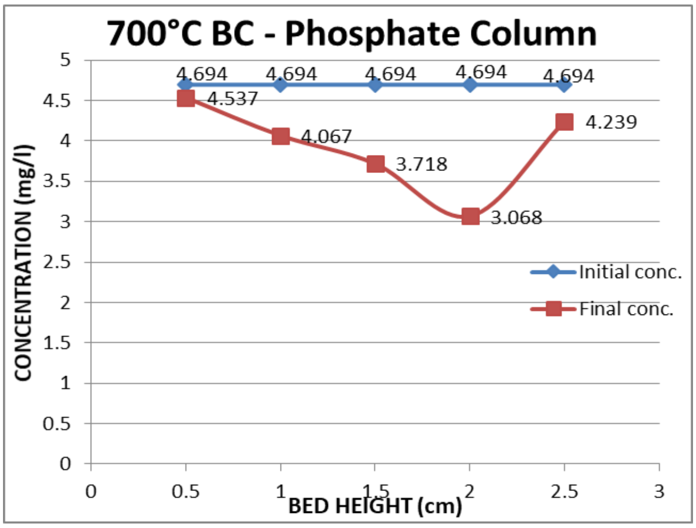

Fig.9.23 Bed height v/s concentration graph for phosphate removal using 700^{0}C CSBC

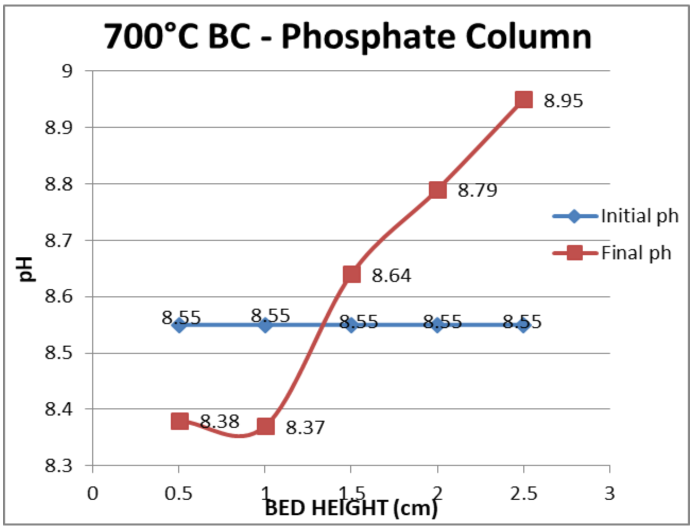

Fig.9.24 Bed height v/s pH graph for phosphate removal using 700^{0}C CSBC

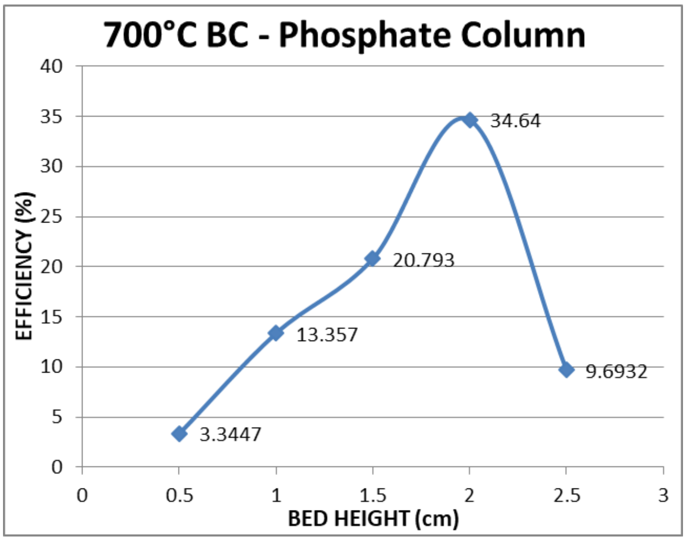

Fig.9.25 Bed height v/s efficiency graph for phosphate removal using 700^{0}C CSBC

2. Coconut Shell Biochar, 445°C at 2hrs 7mins

CSBC pyrolyzed at 445^{0}C were used to remove phosphate from the synthetic sample and various results were obtained. Fig.9.26 shows the bed height v/s concentration graph. Fig.9.27 shows the bed height v/s pH graph and bed height v/s efficiency graph is given in fig.9.28.

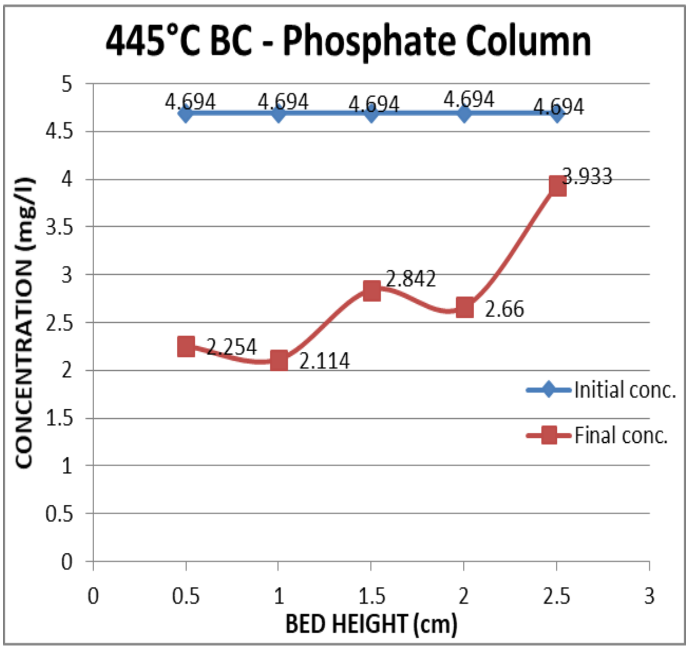

Fig.9.26 Bed height v/s concentration graph for phosphate removal using 445^{0}C CSBC

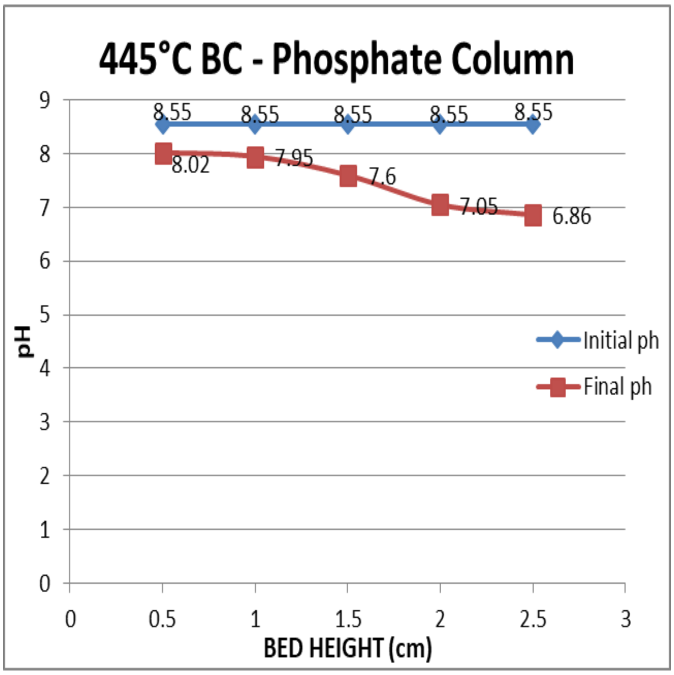

Fig.9.27 Bed height v/s pH graph for phosphate removal using 445^{0}C CSBC

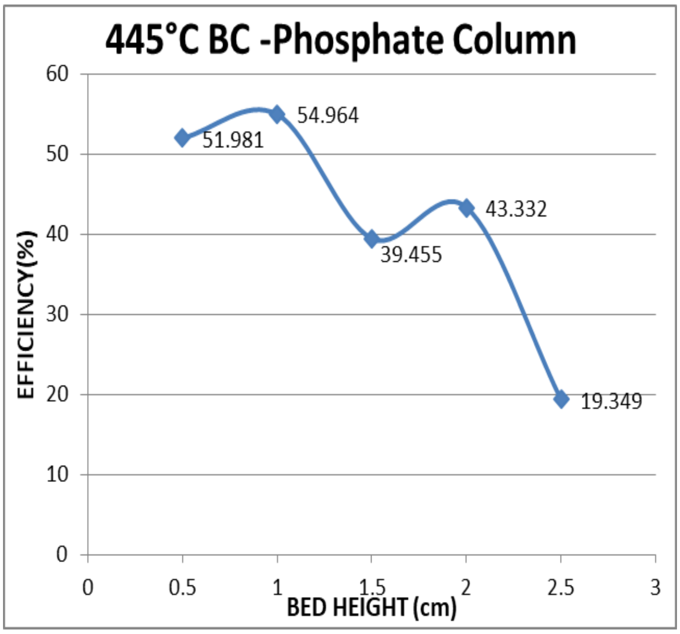

Fig.9.28 Bed height v/s efficiency graph for phosphate removal using 445^0C CSBC

3. Powdered activated charcoal

PAC were used to remove phosphate from the synthetic sample and various results were obtained. Fig.9.29 shows the bed height v/s concentration graph. Fig.9.30 shows the bed height v/s pH graph and bed height v/s efficiency graph is given in fig.9.31.

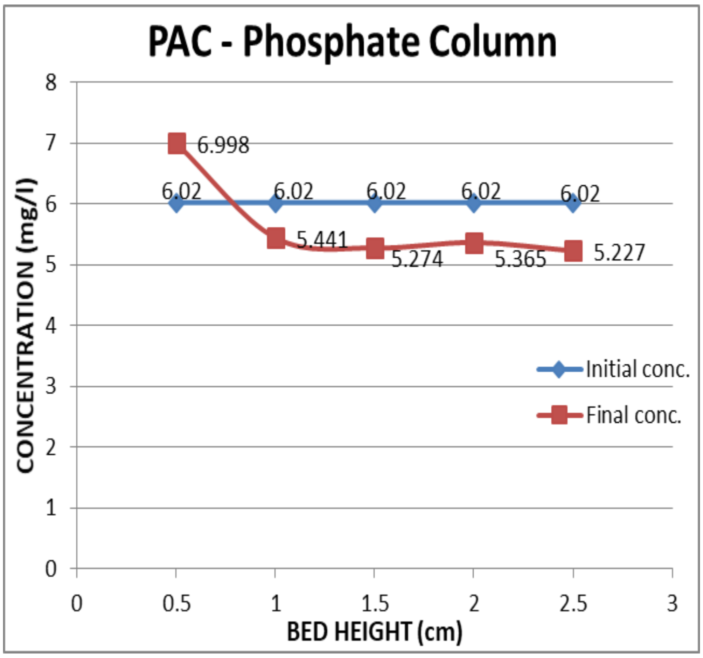

Fig.9.29 Bed height v/s concentration graph for phosphate removal using PAC

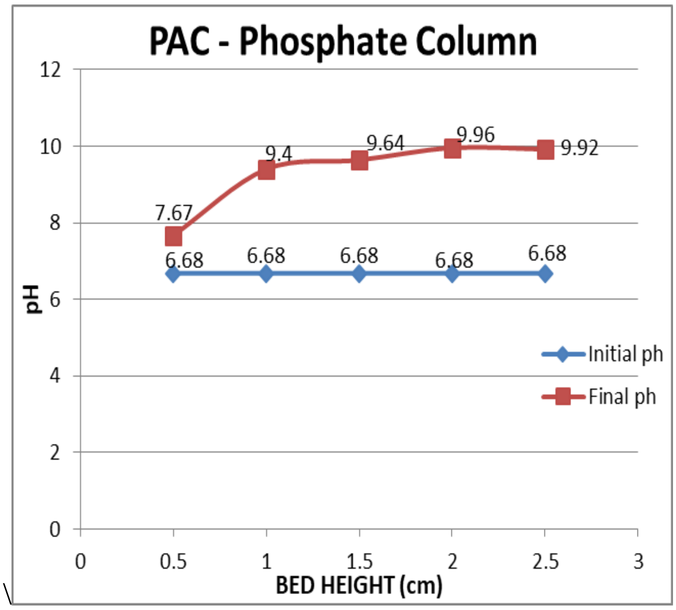

Fig.9.30 Bed height v/s pH graph for phosphate removal using PAC

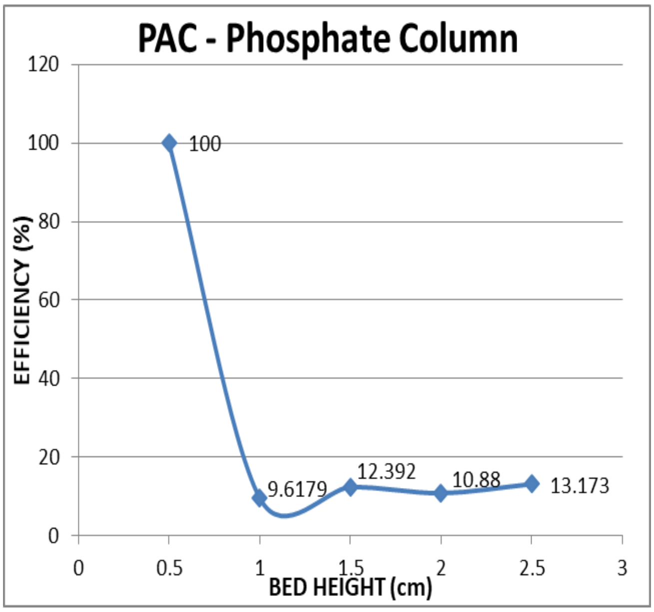

Fig.9.31 Bed height v/s efficiency graph for phosphate removal using PAC

4. Granular activated charcoal

GAC were used to remove phosphate from the synthetic sample and various results were obtained. Fig.9.32 shows the bed height v/s concentration graph. Fig.9.33 shows the bed height v/s pH graph and bed height v/s efficiency graph is given in fig.9.34.

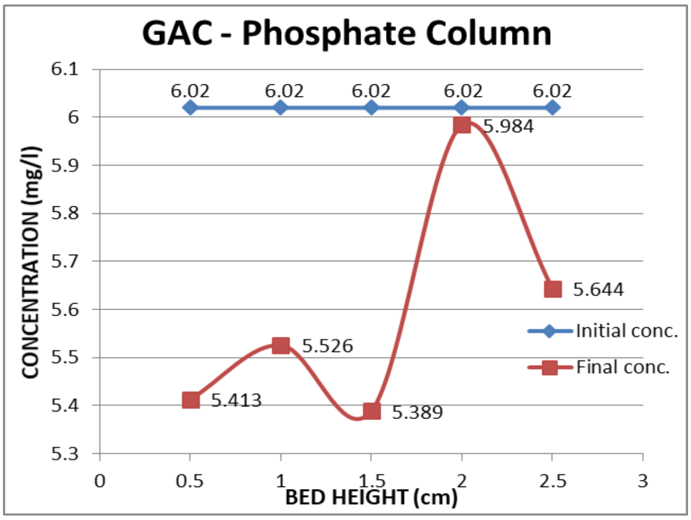

Fig.9.32 Bed height v/s concentration graph for phosphate removal using GAC

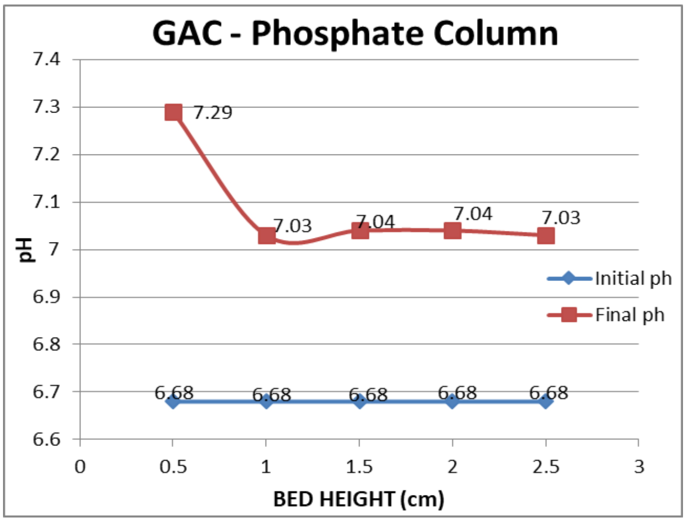

Fig.9.33 Bed height v/s pH graph for phosphate removal using GAC

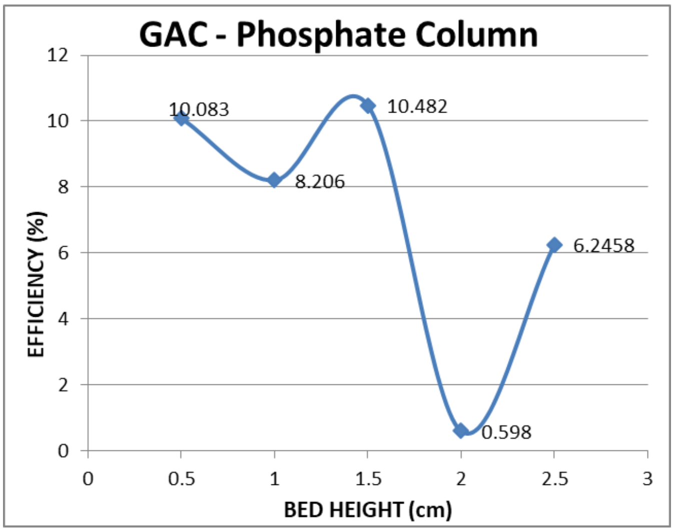

Fig.9.34 Bed height v/s efficiency graph for phosphate removal using GAC

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9.2.5 Combination of Parameters

i) Bed Height v/s Efficiency

The comparison of bed height v/s efficiency graph for the nitrate removal and phosphate removal using various sorbents are given in fig. 9.35 and fig. 9.36 respectively. The sorbents are 700^{0}C CSBC, 445^{0}C CSBC, PAC and GAC. The values at various bed heights are compared here.

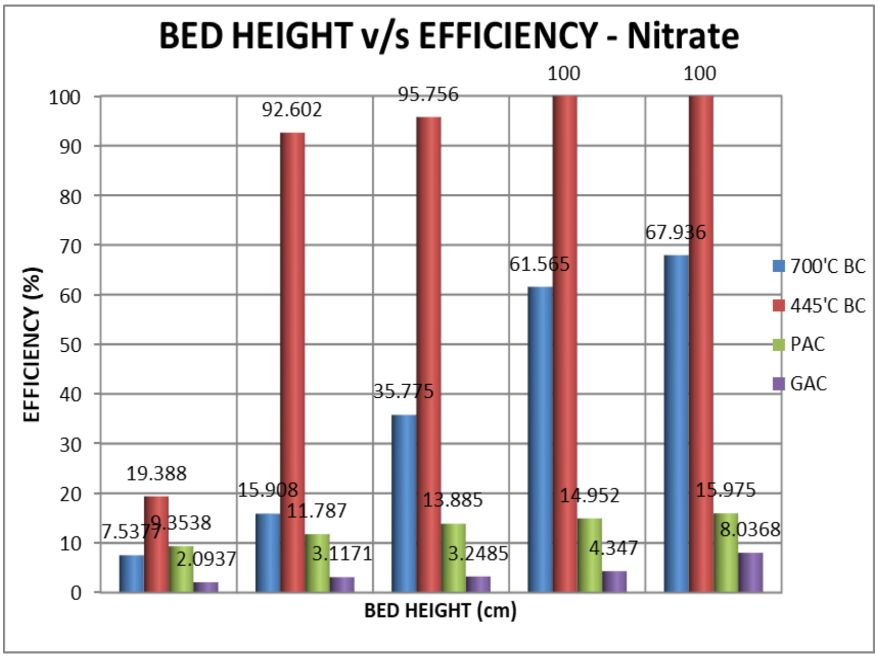

Fig.9.35 Bed height v/s efficiency graph of various sorbents for nitrate removal

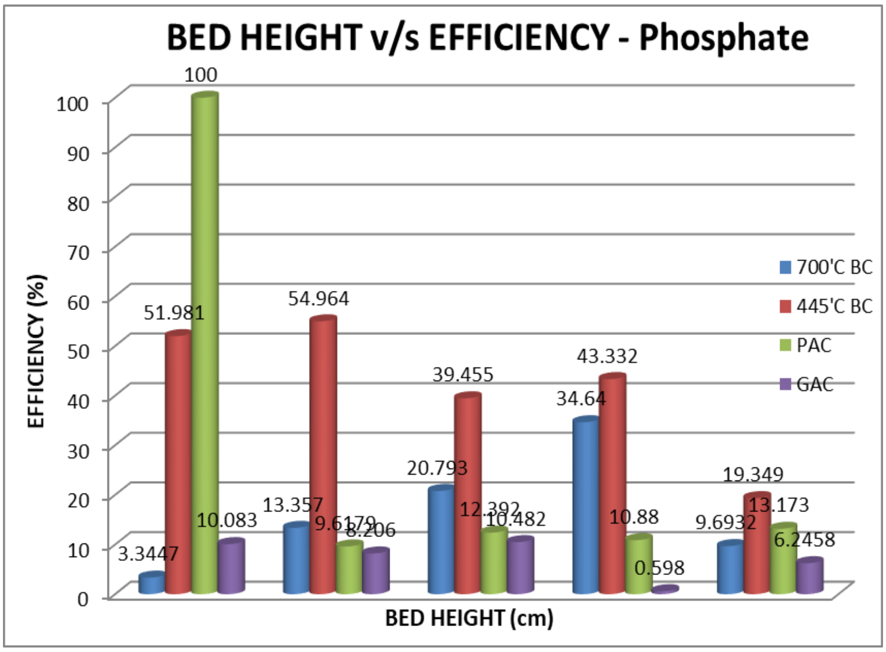

Fig.9.36 Bed height v/s efficiency graph of various sorbents for phosphate removal

ii) Bed Height v/s Change in pH

The comparison of bed height v/s change in pH graph for the nitrate removal and phosphate removal using various sorbents are given in fig. 9.37 and fig. 9.38 respectively. The sorbents are 700^{0}C CSBC, 445^{0}C CSBC, PAC and GAC. The values at various bed heights are compared here.

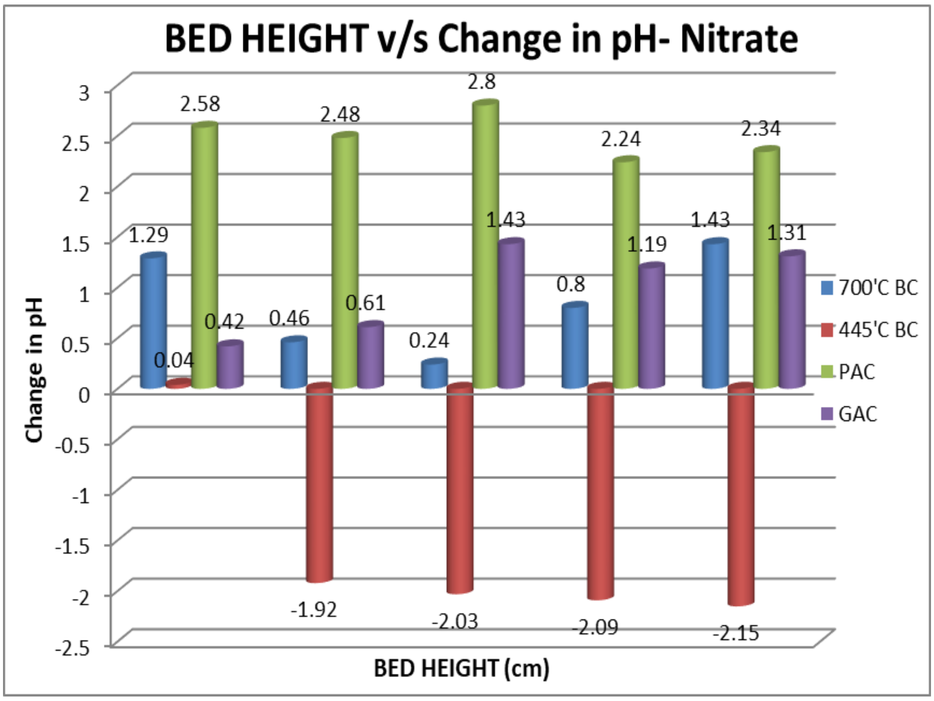

Fig.9.37 Bed height v/s change in pH graph of various sorbents for nitrate removal

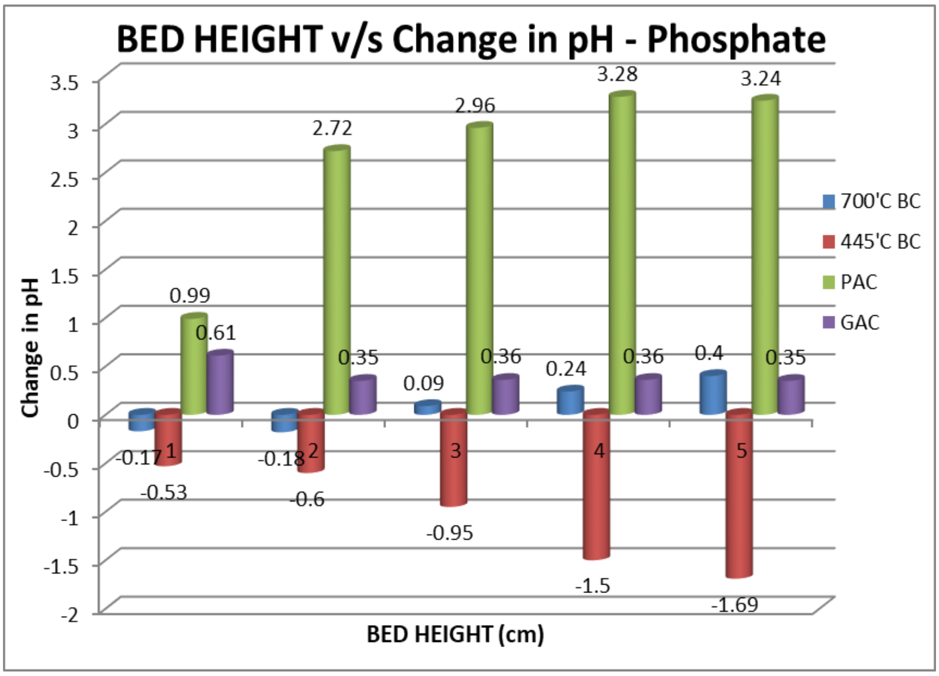

Fig.9.38 Bed height v/s Change in pH graph of various sorbents for phosphate removal

9.2.6 Analysis of the Result

i) Effect of Bed Height

The bed height directly affects the adsorption capacity of the biochar column. A greater bed height provides a larger surface area for adsorption, allowing more contaminants to come into contact with the biochar. As a result, a taller biochar bed accommodate a higher concentration of contaminants and potentially provide a higher adsorption capacity as compared to that of small bed height.

ii) Effect of pH

The pH of the solution plays a significant role in the column absorption treatment using biochar for the removal of nitrate and phosphate from contaminated water. The adsorption capacity of biochar for nitrate and phosphate ions can vary with pH. In general, at a neutral pH, biochar exhibits good adsorption capacity for both nitrate and phosphate. However, as the pH deviates from neutral, the adsorption capacity is affected.

The synthetic water treated with PAC and GAC shows high variation from initial pH, whereas much variations where not observed for synthetic water treated with CSBCs.

9.3 FUTURE SCOPE

Although the project's timeline may pose limitations on its comprehensive completion, it is planned to conduct tests on two different methods of contaminant removal: batch adsorption and column absorption treatment using water hyacinth and wood chips biochars. The primary focus of these experiments is to assess the efficiency of these materials in removing contaminants, specifically nitrate, phosphate and cadmium from water sources.

In the batch adsorption method, controlled laboratory tests will be conducted by introducing predetermined quantities of water hyacinth and wood chips biochar to water samples containing the targeted contaminants. The samples will be agitated and allowed to interact for a specified duration to facilitate adsorption. Subsequently, the concentrations of the contaminants in the water will be measured before and after the adsorption process to evaluate the effectiveness of the materials.

In addition to the batch adsorption method, a column absorption treatment method will be implemented. This method involves passing contaminated water through columns packed with water hyacinth and wood chips biochar. The water will flow through the column at a predetermined rate, allowing the materials to adsorb the targeted contaminants. Samples collected at various stages of the column will be analyzed to determine the extent of contaminant removal.

While the complete assessment of these methods for the removal of nitrate, phosphate, and cadmium is not guaranteed due to time constraints, the project aims to provide valuable insights into the effectiveness of water hyacinth and wood chips biochar as potential solutions for water contamination. These findings can serve as a basis for further research and development in this field.

CHAPTER 10

CONCLUSION

In conclusion, the project focused on evaluating the removal efficiency of coconut shell biochar for nitrate and phosphate contaminants in contaminated water. The project demonstrated that coconut shell biochar has the potential to effectively remove nitrate, while it is less effective in removing phosphate from contaminated water. The biochar exhibited significant adsorption capacity for these contaminants due to its porous structure and high surface area. The project found that the removal efficiency of nitrate and phosphate was influenced by various factors such as contact time, revolutions per minute, initial contaminant concentration, bed height and biochar dosage. Overall, the project contributes to the understanding of coconut shell biochar as a promising adsorbent for the removal of nitrate from water. Through our extensive experimentation and analysis, we have determined that the removal efficiency of nitrate is more effective compared to phosphate using coconut shell biochar.

- Effects on nitrate column method

A taller biochar bed accommodate a higher concentration of contaminants and potentially provide a higher adsorption capacity as compared to that of small bed height. The synthetic water treated with PAC and GAC shows high variation from initial pH, whereas much variations where not observed for synthetic water treated with CSBCs.

- Effects on phosphate column method

CSBC doesn’t show much effectiveness for phosphate removal. This may be due to the presence some other phosphate compounds present in the coconut shell biochar.

- Effects on nitrate batch method

Higher revolutions enhances the adsorption efficiency. The removal efficiency is increased with longer contact times and higher biochar dosages.

- Comparison of CSBC with PAC and GAC

Our findings indicate that coconut shell biochar demonstrates notable effectiveness in removing contaminants during both the batch and column absorption treatment methods. These results suggest that coconut shell biochar could potentially outperform powdered and granular activated charcoal in terms of removal efficiency. However, further comprehensive analysis and experimentation are required to ascertain and validate these promising results.

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APPENDIX

Table 1: Efficiency of CSBC 700°C at 2hrs 7mins on removing nitrate (column method)

Bed height (cm)	Initial pH of sample	Final pH of sample	COD (mg/l)	Removal efficiency (%)
0.5	7.58	8.87	40	7.537688
1	7.82	8.28	32	15.90837
1.5	7.58	7.82	16	35.77537
2	7.82	8.62	24	61.56538
2.5	7.58	9.01	32	67.93617

Table 2: Efficiency of CSBC 445°C at 2hrs 23mins on removing nitrate (column method)

Bed height (cm)	Initial pH of sample	Final pH of sample	Removal efficiency (%)
0.5	7.96	8	19.38785
1	7.96	6.04	92.60163
1.5	7.96	5.93	95.75627
2	7.96	5.87	-
2.5	7.96	5.81	-

Table 3: Efficiency of PAC on removing nitrate (column method)

Bed height (cm)	Initial pH of sample	Final pH of sample	COD (mg/l)	Removal efficiency (%)
0.5	7.58	10.16	24	9.353786
1	7.58	10.06	40	11.78701
1.5	7.58	10.38	28	13.88522
2	7.58	9.82	16	14.95195
2.5	7.58	9.92	44	15.97461

Table 4: Efficiency of GAC on removing nitrate (column method)

Bed height (cm)	Initial pH of sample	Final pH of sample	Removal efficiency (%)
0.5	7.96	8.38	2.0937
1	7.96	8.57	3.117078
1.5	7.96	9.39	3.248521
2	7.96	9.15	4.34701
2.5	7.96	9.27	8.03680

Table 5: Efficiency of CSBC 700°C at 2hrs 7mins on removing phosphate (column method)

Bed height (cm)	Initial pH of sample	Final pH of sample	Removal efficiency (%)
0.5	8.55	8.38	3.344695
1	8.55	8.37	13.35748
1.5	8.55	8.64	20.7925
2	8.55	8.79	34.63997
2.5	8.55	8.95	9.693225

Table 6: Efficiency of CSBC 445°C at 2hrs 23mins on removing phosphate (column method)

Bed height (cm)	Initial pH of sample	Final pH of sample	Removal efficiency (%)
0.5	8.55	8.02	51.98125
1	8.55	7.95	54.96378
1.5	8.55	7.6	39.45462
2	8.55	7.05	43.33191
2.5	8.55	6.86	19.3491

Table 7: Efficiency of PAC on removing phosphate (column method)

Bed height (cm)	Initial pH of sample	Final pH of sample	Removal efficiency (%)
0.5	6.68	7.67	100
1	6.68	9.4	9.61794
1.5	6.68	9.64	12.392
2	6.68	9.96	10.8804
2.5	6.68	9.92	13.1728

Table 8: Efficiency of GAC on removing phosphate (column method)

Bed height (cm)	Initial pH of sample	Final pH of sample	Removal efficiency (%)
0.5	6.68	7.29	10.0831
1	6.68	7.03	8.20598
1.5	6.68	7.04	10.4817
2	6.68	7.04	0.59801
2.5	6.68	7.03	6.24585

Table 9: Efficiency of CSBC 700°C at 2hrs 7mins on removing nitrate (batch method)

Weight (gm)	Revolutions per minute	Initial pH of sample	Contact period	Final pH of sample	Removal efficiency (%)
4	150	8.16	30 mins	8.27	34.48197
		8.16	60 mins	8.11	34.68062
		8.16	90 mins	7.95	31.42573
		8.16	120 mins	7.89	3.109719
4	300	8.16	30 mins	7.34	28.56051
		8.16	60 mins	7.2	31.54798
		8.16	90 mins	7.99	5.432457
		8.16	120 mins	7.42	2.399144
8	150	8.16	30 mins	8.26	21.86736
		8.16	60 mins	8.24	27.93399
		8.16	90 mins	8.26	28.59108
		8.16	120 mins	7.96	33.63386
8	300	8.16	30 mins	7.27	18.03943
		8.16	60 mins	7.68	20.71363
		8.16	90 mins	7.65	22.48625
		8.16	120 mins	7.83	19.36278

Table 10: Efficiency of CSBC 445°C at 2hrs 23mins on removing nitrate (batch method)

Weight (gm)	Revolutions per minute	Initial pH of sample	Contact period	Final pH of sample	Removal efficiency (%)
4	150	7.62	30 mins	9.47	21.19476
		7.62	60 mins	9.23	33.88021
		7.62	90 mins	8.88	41.18063
		7.62	120 mins	8.63	41.56527
4	300	7.62	30 mins	8.74	32.86757
		7.62	60 mins	7.88	32.98532
		7.62	90 mins	7.89	33.09522
		7.62	120 mins	7.16	32.32593
8	150	7.88	30 mins	6.93	21.61115
		7.88	60 mins	6.75	33.52573
		7.88	90 mins	6.17	69.42612
		7.88	120 mins	6.3	44.98681
8	300	7.88	30 mins	7.26	5.672823
		7.88	60 mins	6.8	5.994393
		7.88	90 mins	7.23	12.74736
		7.88	120 mins	7.53	18.58509

Table 11: Efficiency of PAC on removing nitrate (batch method

Weight (gm)	Revolutions per minute	Initial pH of sample	Contact period	Final pH of sample	Removal efficiency (%)
4	150	7.62	30 mins	10.4	-7.00212
		7.62	60 mins	10.41	-7.76356
		7.62	90 mins	10.51	-7.55161
		7.62	120 mins	10.5	-4.95329
4	300	7.88	30 mins	9.7	1.104881
		7.88	60 mins	9.95	5.095646
		7.88	90 mins	10.46	8.970976
		7.88	120 mins	10.26	12.87104
8	150	7.88	30 mins	10.29	2.349934
		7.88	60 mins	10.38	10.8097
		7.88	90 mins	10.05	12.41755
		7.88	120 mins	10.2	13.90996
8	300	7.62	30 mins	10.55	2.527671
		7.62	60 mins	10.77	-6.60962
		7.62	90 mins	10.78	9.043096
		7.62	120 mins	10.83	16.60256

Table 12: Efficiency of GAC on removing nitrate (batch method)

Weight (gm)	Revolutions per minute	Initial pH of sample	Contact period	Final pH of sample	Removal efficiency (%)
4	150	6.86	30 mins	6.46	5.577389
		6.86	60 mins	6.76	8.378627
		6.86	90 mins	6.82	2.976838
		6.86	120 mins	6.98	4.891713
4	300	6.86	30 mins	6.91	0.242495
		6.86	60 mins	6.88	2.41659
		6.86	90 mins	6.7	6.438665
		6.86	120 mins	7.11	13.24525
8	150	6.86	30 mins	8.31	10.73668
		6.86	60 mins	7.2	15.06815
		6.86	90 mins	7.27	7.224684
		6.86	120 mins	7.03	1.597124
8	300	6.86	30 mins	7.43	15.65348
		6.86	60 mins	7.56	18.46308
		6.86	90 mins	7.63	18.49653
		6.86	120 mins	7.64	19.25746

EFFECTS OF SYNTHETIC LEACHATE ON COCONUT SHELL BIOCHAR AND COMPARATIVE STUDY ON ACTIVATED CHARCOAL

A PROJECT REPORT

submitted by

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to

the APJ Abdul Kalam Technological University

in partial fulfilment of the requirements for the award of the Degree

of

Bachelor of Technology

in

Civil Engineering

Department Of Civil Engineering

Vimal Jyothi Engineering College

Chemperi

JUNE 2023

DECLARATION

We undersigned hereby declare that the project report "Effects of Synthetic Leachate on Coconut Shell Biochar and Comparative Study on Activated Charcoal", submitted for partial fulfilment of the requirements for the award of degree of Bachelor of Technology of the APJ Abdul Kalam Technological University, Kerala is a bonafide work done by us under the supervision of Mr. Rojin P. This submission represents our ideas in our own words and where ideas or words of others have been included, we have adequately and accurately cited and referenced the original sources. We also declare that we have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in our submission. We understand that any violation of the above will be a cause for disciplinary action by the institute and the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree, diploma or similar title of any other University.

Place: Chemperi

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CERTIFICATE

This is to certify that the report entitled **"Effects of Synthetic Leachate on Coconut Shell Biochar and Comparative Study on Activated Charcoal"** submitted by **Antus Sunny (VML19CE028), Anura Balakrishnan (VML19CE030), Karthik K (VML19CE059), Treesa Wilson (VML19CE099)** to the APJ Abdul Kalam Technological University in partial fulfilment of the requirements for the award of the Degree of Bachelor of Technology in Civil Engineering is a bonafide record of the project work carried out by them under our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

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ACKNOWLEDGEMENT

First and foremost, we thank god almighty who gave us strength, courage, good health and interest to begin and complete all our task successfully. We express our gratitude to respected principal, **Dr. Benny Joseph** for his permission and constant encouragement. We submit our sincere thanks respected to **Dr. Biju Mathew**, Head of Department of Civil Engineering for his support and timely suggestions. We are thankful to the project coordinator, as well as our project guide **Mr. Rojin P**, Assistant professor in Civil Engineering for his suggestions and guidance. We thank all the faculties of Civil Engineering Department for their limitless support. We profound our sincere thanks to our parents, who always pray for our progress and extend their moral and financial support for our welfare. We also thank our friends, who are with us all the time and positively supporting us in our activities.

ABSTRACT

Now a day's water scarcity is a burning issue. The world's water resources are being deteriorated due to the continuous discharge of a large number of organic and inorganic contaminants. Due to the increase in population, the demand for water also increases. Here comes the necessity of waste water treatment and removal of contaminants, thus making it a potable water. This project focuses on applications in waste water treatment using biochar to remove various pollutants such as heavy metals, chemical and organic compounds. Biochar is a lightweight black residue, made of carbon and ashes, remaining after the pyrolysis of biomass. As an emerging sorbent with great potential, biochar has shown significant advantages such as the broad sources of feed stocks, easy preparation process, and favourable surface and structural properties. Heavy metals in the water environment mostly come from anthropogenic activities such as smelting, mining, and electronic manufacturing effluents. Biochar has been suggested to be used for heavy metals removal from contaminated water. Biochar can be directly used in water and wastewater treatment as a sorbent for contaminants removal. The physical and chemical properties of biochar depend primarily on the types of feedstock and pyrolysis conditions i.e., temperature, residence time, reactor type and heating rate. Though the biochar has an excellent capability to adsorb heavy metal ions from metal contaminated solutions, this capacity is relatively lower in comparison with other known bio sorbents such as activated carbon. Hence there are several approaches to modify the biochar. The contaminated soil and water is treated with biochar and conduct batch method and column method to determine the removal efficiency of contaminants. The results of tests are to be compared and determine the efficiency of prepared biochar over other sorbents. By this comparison, it enables to utilize the biochar instead of the costly bio-sorbents.

Keywords: Biochar, waste water treatment, pyrolysis, heavy metals, sorbents

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LIST OF ABBREVIATIONS

ADS	Adsorption
ASTM	American Standard Test Method
BC	Biochar
BET	Brunauer-Emmett-Teller
COD	Chemical Oxygen Demand
CSBC	Coconut Shell Biochar
CSIF	Central Sophisticated Instrumentation Facility
DES	Desorption
GAC	Granular Activated Charcoal
PAC	Powdered Activated Charcoal
RPM	Revolutions Per Minute
UV	Ultraviolet

` CHAPTER 1

INTRODUCTION

1.1 GENERAL

Water is one of the essential need of the industry as well as life on earth. Now a day's water scarcity is a burning issue. The world's water resources are being deteriorated due to the continuous discharge of a large number of organic and inorganic contaminants. Due to the increase in population, the demand for water also increases. Here comes the necessity of waste water treatment and removal of contaminants, thus making it a potable water. For the treatment of waste water various methods are available like ion-exchange, membrane separation but this need needs more financial input due to that it restrict the use of this method. Among them adsorption by using low cost adsorbent is an effective method for waste water treatment. This project focuses on applications in waste water treatment using biochar to remove various pollutants such as heavy metals and chemical compounds. Biochar is a lightweight black residue, made of carbon and ashes, remaining after the pyrolysis of biomass.

1.2 OBJECTIVES

The project focuses on the following objectives:

- Determination of properties of biochars made from coconut shell.
- Removal of contaminants like PO_4^{3-}, NO_3^- from contaminated water.
- Conduction of batch method and column method to determine the removal efficiency of contaminants from water using biochars.
- Comparison with powdered and granular activated charcoals.

1.3 SCOPE

Nowadays, water is being polluted at a higher rate. A treatment technique with low cost is required for the sustainable treatment of water. Adsorption is a low cost technology and is able to applicable to variety of pollutants. Biochar is used to improve potential carbon sink and soil carbon storage, increase nutrients in soil retention and availability of nutrients, reduction of nutrient leachate and sustain the stability of the ecosystem of the soil. A project of this type gains much importance in a state like Kerala where there are lot of reported cases of lake pollution and polluted ponds which are abandoned.

CHAPTER 2

LITERATURE SURVEY

2.1 GENERAL

The removal of pollutants from contaminated water by using biochar is reviewed in these journals. The preparation of biochar by the pyrolysis method, their properties and their role in the removal of pollutants is studied.

2.2 LITERATURE REVIEW

Masto et al., (2013): Biochar is a useful material for carbon storage in soils. In this report, they explored conversion of water hyacinth (Eichornia crassipes) to biochar as a sustainable weed management strategy, as it also has potential for improving soil quality. The optimum condition for obtaining maxi-mum stable carbon in Eichornia biochar (EBC) is 300–350 °C temperature with 30–40 min residence time. Biochar is a useful material for carbon storage in soils. In this report, the researchers explored conversion of water hyacinth to biochar as a sustainable weed management strategy, as it also has potential for improving soil quality. Soil biochemical properties and maize seedling growth were used to investigate the effects of biochar addition to the soil. The study shows that the waste Eichornia weed could be gainfully utilised as a soil quality amendment material by converting it to EBC.

Patel et al., (2017): It illustrates the procedures of batch and column experiments on water effluent. It gives an idea about the treatment methods and result analysis. Out of the various methods available removal of pollutants on a solid body, adsorption is much effective. Based on literature survey it has been found that the removal of pollutant from effluent waste stream has been carried out by various researcher in batch mode and various kinetic data has been generated. This leaves behind an unexplored area of pollutant removal by adsorption in a continuous mode, which has been selected as a focus of present study.

Zhou et al., (2018): This study aimed to evaluate the adsorption of cadmium and copper by ferromanganese binary oxide-BC composites (FMBC). The biochar were prepared and their physiochemical properties and morphologies were also examined. Kinetic modelling and adsorption isotherms were used to characterize the adsorption of Cu (II) and Cd (II) on FMBC, revealing that adsorption was well represented by pseudo-second-order kinetics and the Langmuir isotherm model. Moreover, adsorption was favoured by increased pH and high

humic acid concentration. X-ray photoelectron spectroscopy and Fourier transform infrared analyses confirmed that the heavy metal ions adsorbed on FMBC were divalent, indicating that the uptake of Cu (II) and Cd (II) was mainly due to the formation of strong mono- or multidentate inner-sphere complexes.

Xue et al., (2019): This study prepared and evaluated seven types of food waste-based biochars (FWBBs) (including meat and bone, starchy staples, leafy stemmed vegetables, nut husks, fruit pericarp, bean dreg and tea leaves). The impacts of raw materials, pyrolysis temperatures, and residence time on the removal of ammonia nitrogen at different ammonia nitrogen concentrations (5, 10, 20, 50, 100, 150 mg/L) were investigated.

Castilla-Caballero et al., (2020): Biochars are emerging eco-friendly products showing outstanding properties in areas such as carbon sequestration, soil amendment, bioremediation, bio composites, and bioenergy. These interesting materials can be synthesized from a wide variety of waste-derived sources, including lignocellulosic biomass wastes, manure and sewage sludge. In this work, abundant data on biochars produced from coconut-shell wastes obtained from the Colombian Pacific Coast are presented. Biochar synthesis was performed varying the temperature and O2 feeding in the pyrolysis reaction. Production yields and some biochar properties such as particle size, zeta potential, elemental content (C, N, Al, B, Ca, Cu, Fe, K, Li, Mg, Mn, Na, P, S, Ti and Zn), BET surface area, FT-IR spectrum, XRD spectrum, and SEM morphology are presented.

Yaashikaa et al., (2020): It focuses on an overview of remediating harmful contaminants utilizing biochar. Production of biochar utilizing various systems has been discussed. It deals with the various methods of biochar production. Production of biochars uncovers a wide variety of biomass that have been utilized as the feedstocks and pyrolyzed by various procedures to handle water pollution. The properties of resultant biochar are significantly influenced by pyrolyis temperature, feedstock, and pyrolysis technology. Biochar can be utilized as major source for removal of toxic pollutants.

Das et al., (2021): It investigates the effect of pyrolysis reactors on the properties of biochar by keeping factors such as feedstock, carbonisation temperature, heating rate and residence time constant. It focuses on the composite applications of biochar. The reactors employed were hydrothermal, fixed-bed batch vertical and fixed-bed batch horizontal-tube reactors. The vertical and tube reactors, at the same temperature, produced biochars having comparable elemental carbon content, surface functionalities, thermal degradation pattern and peak

heat release rates. The hydrothermal reactor, although, a low-temperature process, produced biochar with high fire resistance because the formed tarry volatiles sealed water inside the pores, which hindered combustion.

Liu et al., (2021): Nitrate is one of the most common water contaminants and has caused severe environmental problems. This work aimed to investigate the effects of integration of denitrifier with biochars on nitrate removal and understand the underlying mechanisms. The results showed that physiochemical properties of biochars varied according to different feedstocks, which influenced bacteria attachment and nitrate removal through adsorption. However, bacteria could colonize on biochars no matter biochars surface were favourable for bacteria attachment or not. Immobilization of denitrifier on biochars significantly improved nitrate removal efficiencies and reduced lag time.

Nakhli et al., (2021): In this work, several methods are described for preparing repacked biochar-amended soils. It deals with the pre-column packing, determination of optimum moisture content and bulk density of biochar-amended soils. The modifications are rinsing and oven-drying biochar, determining the optimum moisture content to achieve a homogenous mixture, determining the desired bulk density before column packing, and mixing and packing under wet conditions.

Antunes et al., (2022): In this study, researchers investigate on the phosphorous removal, by using algae biochar. A potential circular economy approach for microalgae was investigated considering the crucial stages of bio refinery. Important stages, such as drying of biomass, production of biochar (pyrolysis), and application of biochar for phosphorus removal were studied and reported. The physicochemical properties of biomass as well as biochar were characterized and were correlated with their capacity to adsorb phosphorus (P).

Wang et al., (2022): This work investigates on the impact of the biochar microstructure on the hydraulic conductivity of sand-biochar mixtures. It experimentally investigated the hydraulic properties of sand-biochar mixtures for uniformly graded sand. This approach enables to statically evaluate the interparticle porosity and tortuosity of biochar. The researchers showed that by excluding biochar’s intraparticle porosity, the hydraulic conductivity prediction accuracy can be significantly improved, thus providing a more accurate prediction of the hydraulic behaviour of the soil-biochar filters.

2.3 LITERATURE GAP

Although several studies have investigated the removal efficiency of biochar in various applications, there is a significant literature gap regarding its effectiveness in the removal of heavy metals and chemical compounds from contaminated water sources. While some research has touched upon this topic, existing studies predominantly focus on organic pollutants or agricultural applications of biochar. Limited attention has been given to assessing the potential of biochar as an efficient and sustainable adsorbent for heavy metal removal, particularly in industrial wastewater treatment scenarios. Therefore, this project aims to fill this literature gap by investigating the removal efficiency of coconut shell biochar in the context of nitrate and phosphate contaminated water.

CHAPTER 3

METHODOLOGY

3.1 GENERAL

The methodology for biochar treatment in wastewater can be summarized into several key steps. They are biochar preparation, preparation of synthetic water sample, conduction of iodine value test, conduction of batch and column methods of treatment, evaluation and analysis of results at various parameters.

3.2 BIOCHAR PREPARATION

Coconut shell biochar is a type of biochar derived from coconut shells, which are a waste product of the coconut industry. The preparation of coconut shell biochar involves several steps. They are collection and preparation of coconut shells, carbonization, heating and pyrolysis, cooling and quenching, crushing and sizing and storage.

3.3 PREPARATION OF SYNTHETIC WATER SAMPLE

Synthetic water samples containing nitrates and phosphates are laboratory-prepared solutions used for experimental purposes to simulate the presence of these contaminants in water. In the laboratory, synthetic water samples containing nitrates and phosphates are used for various purposes, including studying the behaviour and treatment of these contaminants, assessing the effectiveness of treatment technologies, conducting adsorption experiments.

3.4 CONDUCTION OF IODINE VALUE TEST

The iodine value test is a common method used to determine the efficiency of biochar in adsorbing organic compounds. Specifically, it measures the amount of iodine in milligrams that can be adsorbed by a certain weight of biochar material. The iodine value test provides an indication of the surface area and porosity of the biochar, as well as its potential for adsorbing organic pollutants. It is important to note that the test results should be interpreted in conjunction with other characterization and performance tests to fully assess the effectiveness of the biochar for specific applications.

3.5 CONDUCTION OF BATCH EXPERIMENT

Batch tests were performed to find out the maximum capacity of adsorbent. For conducting batch experiment 200ml of sample is to be taken in a beaker in which 4 gm and 8gm of biochar is to be added in to the beaker and putting on to the magnetic stirrer and stirring is started at 150 and 300 revolutions per minutes respectively. 50 ml of sample is to be drawn in time interval of 30, 60, 90 and 120 minutes from this beaker. Then filtered on Whatman filter paper and the filtrate is analyzed in spectrophotometer for respective concentration. At the end of 2hr the stirring is stopped and the experiment is terminated.

3.6 CONDUCTION OF COLUMN EXPERIMENT

Column tests were then to be performed to provide a real-life treatment process but on a smaller scale. Continuous experiment were carried out in glass column having 7.5 cm length and 5 cm diameter, in which adsorbent was filled in the column and at the top and bottom filter beds are placed for the supporting purpose. Effluent sample was feed from top and the sample was collected from the bottom. The experiment were carried out by changing the bed height of adsorbent as 0.5 cm, 1 cm, 1.5 cm, 2 cm and 2.5 cm for coconut shell biochar, powdered activated charcoal and granular activated charcoal.

3.7 EVALUATION AND ANALYSIS OF RESULT

The analysis of the respective concentration of filtrate effluent sample is done by using UV-Visible Double Beam Spectrophotometer.

CHAPTER 4

BIOCHAR

4.1 GENERAL

Biochar is the lightweight black residue, made of carbon and ashes, remaining after the pyrolysis of biomass. Biochar is defined by the International Biochar Initiative as "the solid material obtained from the thermochemical conversion of biomass in an oxygen-limited environment". Biochar is a stable solid that is rich in pyrogenic carbon. Biochar can be produced from almost as many types of feedstock as there are types of biomass including: agricultural wastes, rice husks, bagasse, paper products, animal manures, and even urban green waste.

4.2 COCONUT SHELL BIOCHAR

Coconut shell biochar refers to a type of charcoal-like substance that is produced from coconut shells through a process called pyrolysis. Pyrolysis involves heating the coconut shells in the absence of oxygen, which leads to the decomposition of organic material and the production of biochar. Coconut shell biochar is known for its high carbon content, porous structure, and stable composition. In environmental remediation, coconut shell biochar is utilized for its adsorption properties. It can effectively remove pollutants, heavy metals, and organic contaminants from water and soil. Its porous structure provides a large surface area for adsorption, making it an environmentally friendly and cost-effective solution for water and soil treatment. The CSBC is shown in fig.4.1.

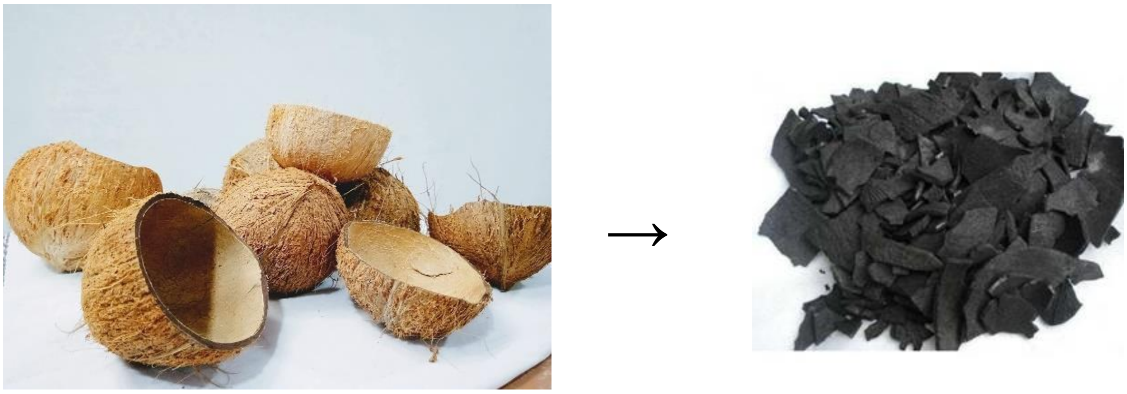


Fig. 4.1 Coconut shell biochar (Caballero et al. 2020)

CHAPTER 5

BET ANALYSIS

5.1 GENERAL

Brunauer-Emmett-Teller (BET) surface area analysis is the multi-point measurement of an analyte's specific surface area (m2/g) through gas adsorption analysis, where an inert gas such as nitrogen is continuously flowed over a solid sample, or the solid sample is suspended in a defined gaseous volume.

5.2 BET MEASUREMENT

BET analysis requires measurement of an adsorption isotherm. Because the BET model uses the relative pressure of the adsorptive, it is necessary that the gas be condensable at the adsorption temperature or the gas is really a vapour.
The measurement involves:

- Putting a known amount of sample into a sample cell or container.
- Outgassing or other treatment of the sample, to remove impurities and moisture.
- Increasing the pressure of the gas, while measuring the amount adsorbed on the surface of the sample. For the best precision, this is done at a number of discrete pressures, and with a wait for equilibrium and measurement of the amount adsorbed at each point.
- The saturation vapour pressure is measured at the same time, or it may be calculated from knowledge of the temperature.
- BET is most widely performed using adsorption of Nitrogen gas at 77 K, the boiling point of liquid nitrogen, but other species and temperatures are also used such as Argon at 87 K (liquid Argon temperature), Krypton at 77 K, Carbon dioxide at 0 °C or at 25 °C, etc.

5.3 BET ANALYSIS RESULTS

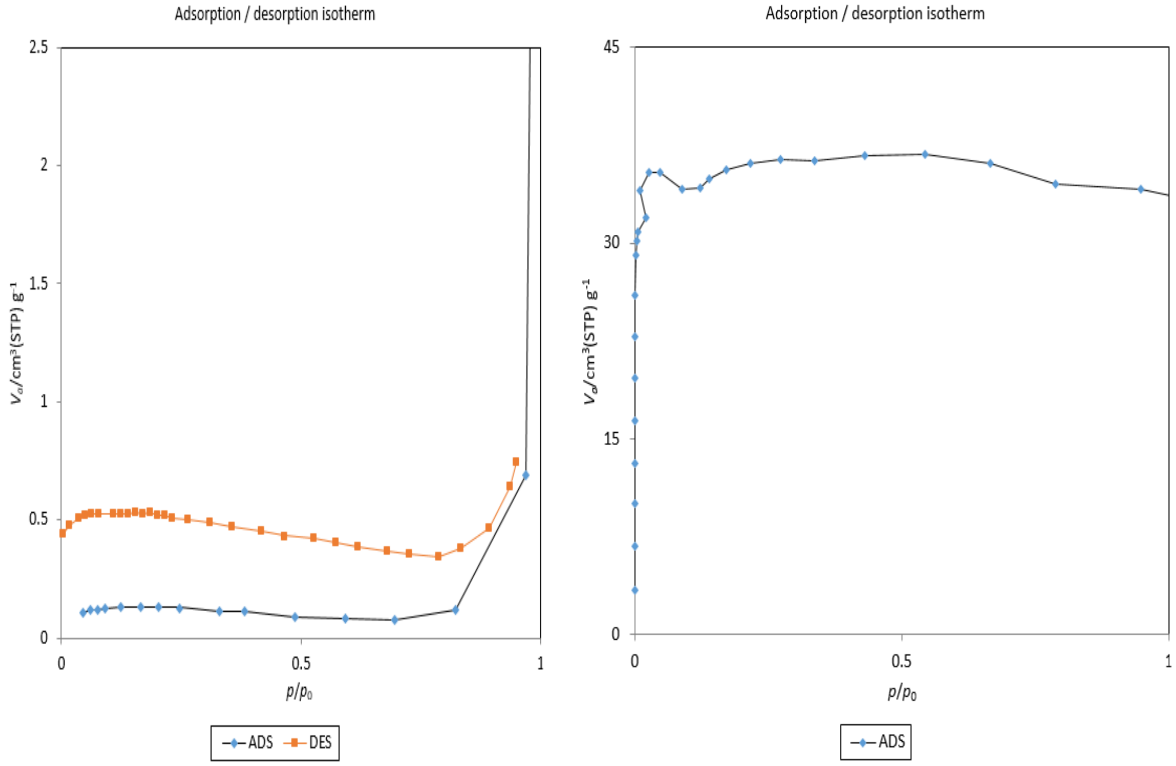
5.3.1 General

The BET (Brunauer-Emmett-Teller) Surface Area Analysis were conducted for coconut shell biochars pyrolyzed at 700^0C and 445^0C from Central Sophisticated Instrumentation Facility (CSIF), University of Calicut. The analysis was performed using adsorption of Nitrogen gas at adsorption temperature of 77 K.

5.3.2 Adsorption/desorption isotherm

A plot of relative pressure verses volume adsorbed obtained by measuring the amount of an inert gaseous or liquid substance (sorbent, usually H2 or N2) which adsorbs onto the surface of interest (sorbate), and the subsequent amount that desorbs at a constant temperature. That is, relative pressure 'p/p_0'(where, 'p' is the partial vapour pressure of adsorbate gas in equilibrium with the surface and 'p_0' is the saturated pressure of adsorbate gas) in X-axis and volume adsorbed 'V_a' in Y-axis.

The obtained adsorption/desorption isotherm for coconut shell biochars pyrolyzed at 445^{0}C and 700^{0}C are shown in fig.5.1.

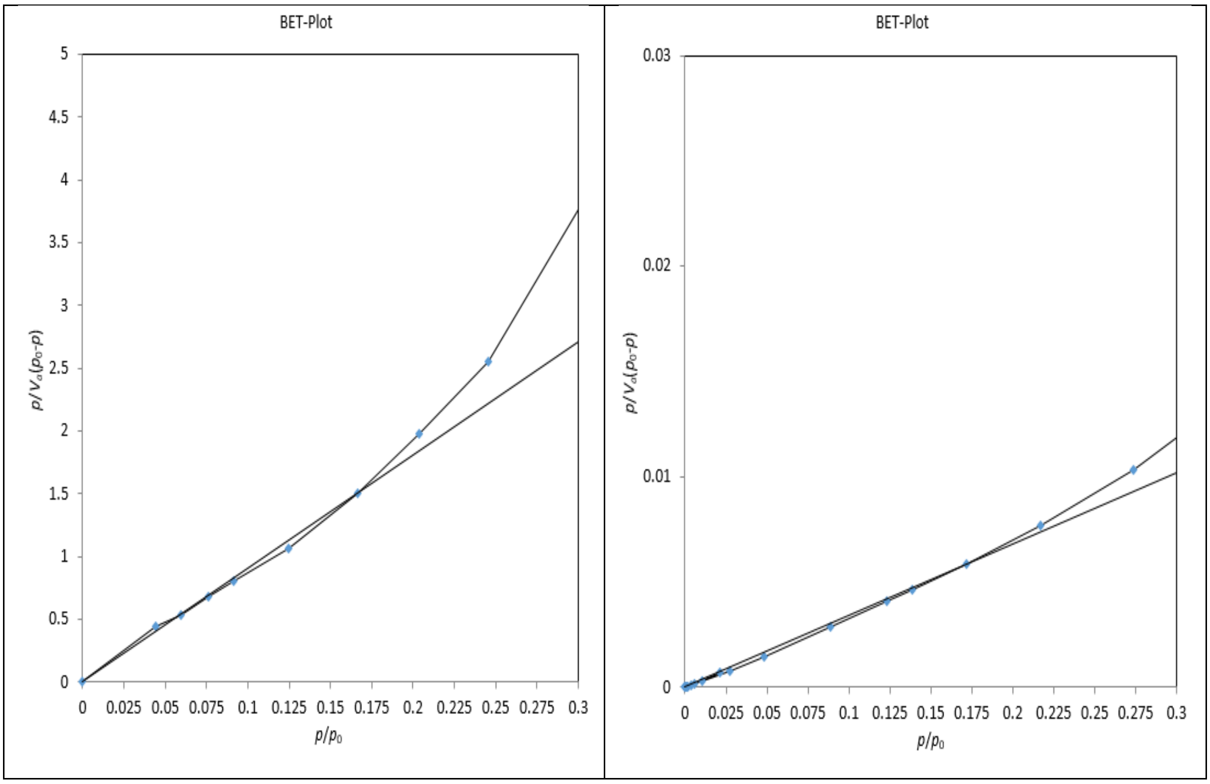


(a) (b)

Fig.5.1 Adsorption/desorption isotherm of CSBC 445^{0}C (a) and CSBC 700^{0}C (b)

5.3.3 BET Plot

A plot of $(p/Va\ (p_0 - p))$ against (p/p_0), is called the BET plot, where 'p' is the partial vapour pressure of adsorbate gas in equilibrium with the surface, 'p_0' is the saturated pressure of adsorbate gas and 'Va' is the volume adsorbed. The obtained BET plot for coconut shell biochars pyrolyzed at 445^{0}C and 700^{0}C are shown in fig.5.2.



(a) (b)

Fig.5.2 BET plot of CSBC 445^{0}C (a) and CSBC 700^{0}C (b)

The obtained results of the biochars after the BET plot are given in table 5.1.

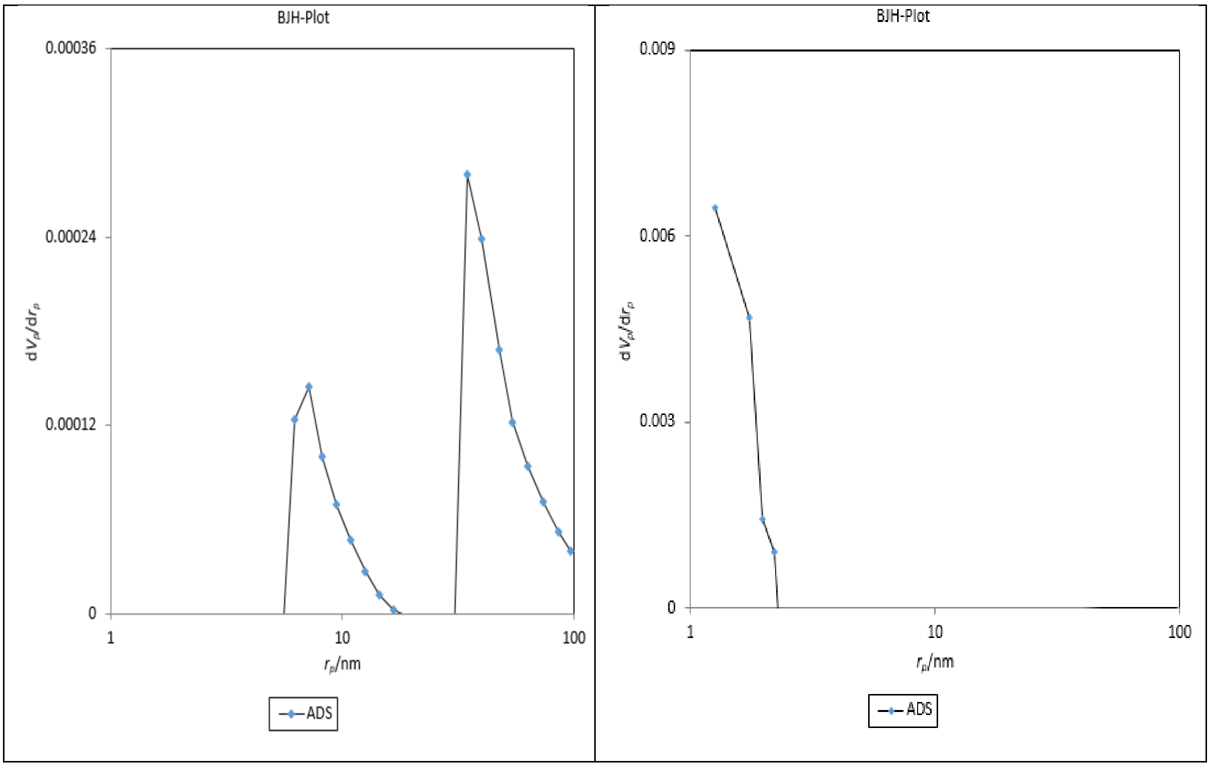
Table 5.1. BET plot results

Parameters	Coconut Shell Biochar-445^{0}C	Coconut Shell Biochar-700^{0}C
Surface area, m^2/g	0.48234	128.3
Vm, monomolecular adsorption volume, cm^3/g	0.1108	29.477
Total pore volume, cm^3/g	0.0079141	0.052196
Mean pore diameter, nm	65.631	1.6273

From the result we can understand that the 700^{0}C pyrolyzed CSBC has more surface area than 445^{0}C CSBC.

5.3.4 BJH Plot

BJH is a method to determine pore size distribution. The graph is obtained by percentage change of pore volume ($\Delta V_p/ \Delta r_p$) against micropore radius (r_p). The obtained BJH plot for coconut shell biochars pyrolyzed at 445^{0}C and 700^{0}C are shown in fig.5.3. The results obtained from the BJH method are given in table 5.2.



(a) (b)

Fig.5.3 BJH plot of CSBC 445^{0}C (a) and CSBC 700^{0}C (b)

Table 5.2 BJH method results

Parameters	Coconut Shell Biochar-445^{0}C	Coconut Shell Biochar-700^{0}C
Pore volume, V_p, cm^3/g	0.0076571	-0.00052113
Pore radius, r_p, nm	34.75	1.26
Surface area of pore, a_p, m^2/g	-0.08798	5.8781

Signature Not Verified

Principal.VJEC

CHAPTER 6

PREPARATION OF BIOCHAR

6.1 GENERAL

The common thermochemical techniques used for biochar production include pyrolysis, hydrothermal carbonization, gasification, flash carbonization and torrefaction. Of all these methods, pyrolysis is the most commonly used to produce biochar.

6.2 SLOW PYROLISIS

Slow pyrolysis is the method used when char is the primary product. The general method is running the process between 400 to 800 °C and has a heating rate under 10 °C per minute. The feedstock used in the process is of larger particle size, several methods can use large pieces of wood if the feeding system can handle it. To optimize the production of char vapour is kept in the process for a longer duration of time. These technologies have been known and used for a long time. New industrial processes for slow pyrolysis is producing both char and can collect the other products or use them for heat and power production. The bio-oil can also contain valuable chemicals such as acetone, methanol and acetic acids. A slow pyrolysis process can have several stages for separation of the products created in the process. In general, a slow pyrolysis process produces char and gas, some parts of the product gas can be condensed into liquid fractions. The amount is these product is affected by the type of feedstock and process set up. Depending on market demand for the various products the process should be developed to maximize profit for the situation.

6.3 PROCEDURE FOR PREPARATION OF BIOCHAR

The physical and chemical properties of biochar depend primarily on the types of feedstock and pyrolysis conditions i.e., temperature, residence time, reactor type and heating rate. The biochar has a great potential for sorption from aqueous solutions

6.3.1 Selection of Feedstock:

Any organic material can be used as a feedstock for making biochar, such as wood chips, coconut shells, or water hyacinth. Choose a feedstock that is readily available in our area and that will produce a high-quality biochar.

6.3.2 Drying:

Once the feedstock is selected, it needs to be dried to remove the moisture content. This is done by spreading the material out in the sun or by using a drying machine.

6.3.3 Preparation of Feedstock:

If the feedstock is in large pieces, it may need to be chipped or shredded into smaller pieces that are suitable for pyrolysis.

6.3.4 Load the Pyrolysis Chamber:

The pyrolysis chamber can be any container that can withstand high temperatures, such as a carbonizer. The schematic diagram of carbonizer is shown in fig.6.1. Fill the carbonizer with the prepared feedstock, leaving enough space for air to circulate around the material.

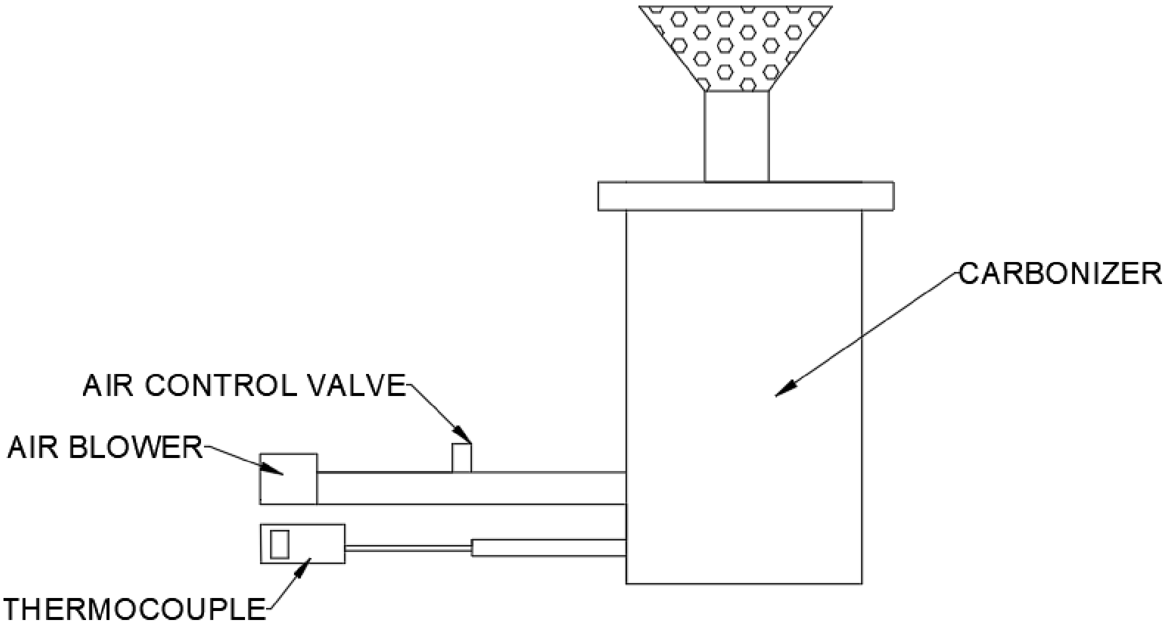


Fig.6.1 Schematic diagram of carbonizer

6.3.5 Heat the Chamber:

Start a fire at the bottom of the chamber to heat the feedstock. The fire should be hot enough to pyrolyze the feedstock, but not so hot that it burns it completely to ash. Cover the chamber

to limit the amount of oxygen that enters and allow the pyrolysis process to take place. Fig. 6.2 shows the various stages of preparation of biochar.

Fig 6.2 Preparation of biochar

6.3.6 Monitor the Process:

The pyrolysis process can take several hours to complete, depending on the size of the feedstock and the temperature of the fire. Monitor the process to ensure that the biochar is not overcooked or undercooked. When the process is complete, the biochar should be dark in colour and have a light, porous texture.

6.3.7 Cool and Store the Biochar:

Once the pyrolysis process is complete, allow the biochar to cool before removing it from the chamber. Store the biochar in a dry place to prevent it from absorbing moisture and losing its effectiveness.

6.4 BIOCHARS PREPARED

For a maximum yield of biochar, the technique chosen for production must be appropriate depending on the biomass type and also the process conditions such as heating rate, temperature, residence time, etc. must be optimum. These conditions are crucial since they may affect the physical and chemical states of biochar during the production process. The biochars prepared on various temperature and residence time are shown in the table 6.1.

Table 6.1: Biochars prepared

BIOCHAR TYPE	TEMPERATURE (°C)	DURATION	DATE
COCONUT SHELL BIOCHAR	502.8	1 hr 22 min	15/11/2022
	809.3	2 hrs 16 min	23/11/2022
	700	1hr 40 min	22/12/2022
	445	2 hrs 23 min	22/12/2022
	716	2 hrs 22 min	25/12/2022
	700	2 hrs 7 min	26/12/2022
	700	1 hr 39 min	26/12/2022
	700	1 hr 27 min	27/12/2022
	702	1 hr 24 min	28/12/2022
	700	1 hr 38 min	28/12/2022
	700	2 hrs 10 min	28/12/2022
	800	1 hr 35 min	29/12/2022

CHAPTER 7

IODINE VALUE TEST FOR BIOCHAR

7.1 GENERAL

American standard test method (ASTM D4607-94, 2006) was used to determination of iodine number of activated carbon. The amount of iodine absorbed [mg/g (carbon)] at residual iodine concentration of 0.02N is reported as iodine number. The Iodine number test is commonly used method to measure the surface area of biochar. This test is based on the principle that iodine is absorbed by the surface of the biochar, and the amount of iodine absorbed is proportional to the surface area of the biochar. The iodine number is a relative indicator of porosity in an activated carbon. It does not necessarily provide a measure of the carbon's ability to absorb other species. This test method is based upon a three-point adsorption isotherm.

7.2 MATERIALS REQUIRED

These are the various materials required for the iodine value test:

- Analytical balance
- Biochar sample
- Erlenmeyer flask
- Desiccator
- Burette
- Conical flask
- Pipette
- Whatman filter paper
- Funnel

7.3 REAGENTS

The various reagents used for the iodine value test are listed below:

- Hydrochloric acid (HCl): Dilute 70ml conc. HCl to 550ml distilled water.
- Sodium thiosulphate ($Na_2S_2O_3$) solution (0.1N): Add 24.82g $Na_2S_2O_3$ to 75ml distilled water. Add 0.1g Na_2CO_3 to it and dilute to 1L.

- Standard Iodine solution (0.1N): Weigh 12.7g iodine and 19.1g KI, mix it with 2 to 5ml distilled water and dilute it to 1L.
- Potassium Iodate solution (0.1N): Add 100 ml distilled water to 3.5667g KIO_3 and dilute it to 1L.
- Starch solution

7.4 PROCEDURE

- Weighted the three biochar dosages of individual temperature (W_1, W_2, W_3 grams) using electronic balance.
- Each weighted sample of carbon was transferred to a clean, dry 250cm³ Erlenmeyer flask equipped with a ground glass stopper.
- 10ml of HCl solution is added to each flask containing carbon. Each flask is stopped and swirled gently until the carbon is completely wetted.
- The stoppers are loosened to vent the flasks and they are heated to bring the contents to boil for 30 sec. The flasks are removed and cooled in room temperature (29ºC).

Fig. 7.1 Titration

- 100ml of 0.1N iodine solutions are pipetted in to each flask. The addition of iodine solution to the three flasks are staggered to minimize delay in handling.
- The flask is immediately stoppard and shaken vigorously for 30seconds. Each mixture is quickly filtered by gravity through one sheet of folded Whatman filter paper.
- Clean beakers are used to collect the filtrates. Each filtrate is swirled and 50ml of it is pipetted in to clean 250cm³ Erlenmeyer flask.

- Each filtrate is titrated with 0.1N sodium thiosulphate solutions until the solution turned yellow as shown in fig.7.1.
- 2ml of freshly prepared starch indicator solution is added and the titration continued with sodium thiosulphate until one drop produced a colourless solution.
- The volume of sodium thiosulphate used is noted.

7.5 EQUATION

Two calculations are required for each carbon dosage, as X/M and C.

Iodine absorbed (X/M) per gram of carbon (mg/g) is calculated as follows:

$$\frac{X}{M} = \frac{[A-(DF)(B)(S)]}{M} \qquad \rightarrow \qquad (1)$$

Where,

A= (N_2) iodine (12693.0)

N_2=Iodine (N) = 0.1

S=Sodium thiosulphate (cm^3)

M=Carbon used (g)

DF=Dilution factor= (100+10)/50=2.2

B= (N1) (126.93)

N_1=Sodium thiosulphate (N) = 0.1

The residual filtrate (C) is calculated as follows:

$$C = \frac{N1 * S}{F} \qquad \rightarrow \qquad (2)$$

Where,

N_1 = Sodium thiosulphate (N) = 0.1

F = Filtrate, mL

S = Sodium thiosulphate, mL

Carbon dosage can be estimated as follows:

$$M = \frac{[A-(DF)(C)(126.93)(50)]}{E} \qquad \rightarrow \qquad (3)$$

Where,

M= Carbon, gm

A= $(N_2)(12693.0)$

DF= Dilution factor

C= Residual iodine

E= Estimated iodine number of carbon

Three carbon dosages are calculated using three values of C (usually 0.01, 0.02 and 0.03).

7.6 IODINE VALUE TEST 1

The below tables show the observations, calculations, result and inference of the iodine value test conducted for coconut shell biochar.

7.6.1 Observations

The observed values of iodine value test titrations carried out in Set 1 (75µ passing) and Set 2 (75µ retained) are tabulated in table 7.1.

Table 7.1: Observation of titrations

Set No.	Trial No.	Weight of biochar (g)	Volume of biochar (ml)	Burette reading of $Na_2S_2O_3.5H_2O$ (ml)			Volume of $Na_2S_2O_3.5H_2O$ consumed (ml)
				Initial reading (ml)	Intermediate reading (ml)	Final reading (ml)	
1	1	1.450	50	0	36.8	39.7	39.7
	2	1.980	50	0	27.4	28.7	28.7
	3	2.259	50	0	30.8	32.3	32.3
2	4	1.700	50	0	40.2	41.7	41.7
	5	1.980	50	0	40.8	43.1	43.1
	6	2.259	50	0	40.2	41.6	41.6

7.6.2 Calculations

The tables 7.2 and 7.3 shows the calculations for X/M and C values, using equations (1), (2) and (3).

Table 7.2: Calculations for the y axis of the graph

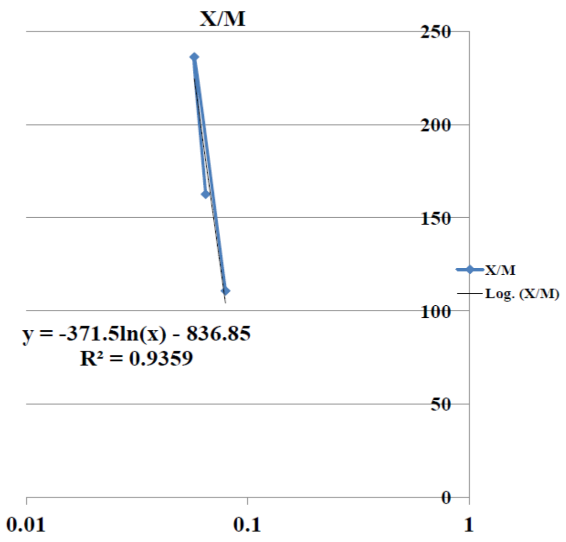
X/M								
	N1	N2	A	DF	B	S	M	X/M
1	0.1	0.1	1269.3	2.2	12.693	39.7	1.45	110.82300
	0.1	0.1	1269.3	2.2	12.693	28.7	1.98	236.29490
	0.1	0.1	1269.3	2.2	12.693	32.3	2.259	162.60970
2	0.1	0.1	1269.3	2.2	12.693	41.7	1.7	61.67305
	0.1	0.1	1269.3	2.2	12.693	43.1	1.98	33.20694
	0.1	0.1	1269.3	2.2	12.693	41.6	2.259	47.64792

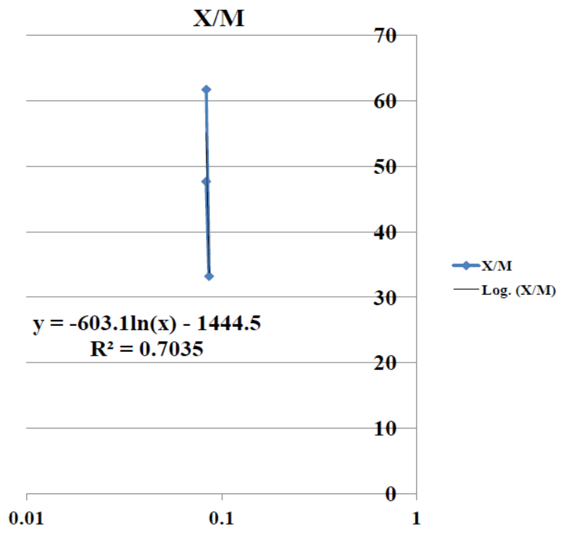
Table 7.3: Calculations for the x axis of graph

Set No.	C			
	N1	S	F	C
1	0.1	39.7	50	0.0794
	0.1	28.7	50	0.0574
	0.1	32.3	50	0.0646
2	0.1	41.7	50	0.0834
	0.1	43.1	50	0.0862
	0.1	41.6	50	0.0832

7.6.3 Graphical Representation

The graph shown in fig.7.2 is the graphical representation for iodine value test. It is obtained by plotting X/M (as shown in table 7.2) on X-axis and C (as shown in table 7.3) on Y-axis.





Set 1 Set 2

Fig.7.2 Graphical representation for the iodine test 1

7.6.4 Results from Graph

Iodine Value of Biochar;

- Set 1

  R^2=0.9359

  y=-371.5 ln(x)-836.85=-371.5 ln(0.02)-836.85=616.46

- Set 2

  R^2=0.7035

  y=-603.1ln(x)-1444.5=-603.1 ln(0.02)-1444.5=914.841

  Where, R^2 is the regression coefficient

7.6.5 Inference

Based on the obtained iodine value of the coconut shell biochar, it can be inferred that the biochar possesses a relatively high degree of unsaturation. This suggests that the biochar may have significant potential as an absorbent material for capturing and removing pollutants.

7.7 IODINE VALUE TEST 2

The below tables show the observations, calculations, result and inference of the iodine value test conducted for coconut shell biochar.

7.7.1 Observations

The observed values of iodine value test titrations carried out in Set 1, 2 and 3 (425µ passing) are tabulated in table 7.4.

Table 7.4: Observation of titrations

Set No.	Trial No.	Weight of biochar (g)	Volume of biochar (ml)	Burette reading of $Na_2S_2O_3.5H_2O$ (ml)			Volume of $Na_2S_2O_3.5H_2O$ consumed (ml)
				Initial reading (ml)	Intermediate reading (ml)	Final reading (ml)	
1	1	5.6690	50	0	30.7	31.6	31.6
	2	6.6003	50	0	21.6	22.8	22.8
	3	7.5310	50	0	30.8	31.8	31.8
2	4	4.2520	50	0	33.9	34.6	34.6
	5	4.9500	50	0	30.4	31.4	31.4
	6	5.6480	50	0	28	29	29
3	7	2.8340	50	0	29.1	30	30
	8	3.3001	50	0	29.5	30.6	30.6
	9	3.7650	50	0	30.4	30.8	30.8

7.7.2 Calculations

The tables 7.5 and 7.6 shows the calculations for X/M and C values, using equations (1), (2) and (3).

Table 7.5: Calculations for the y axis of graph

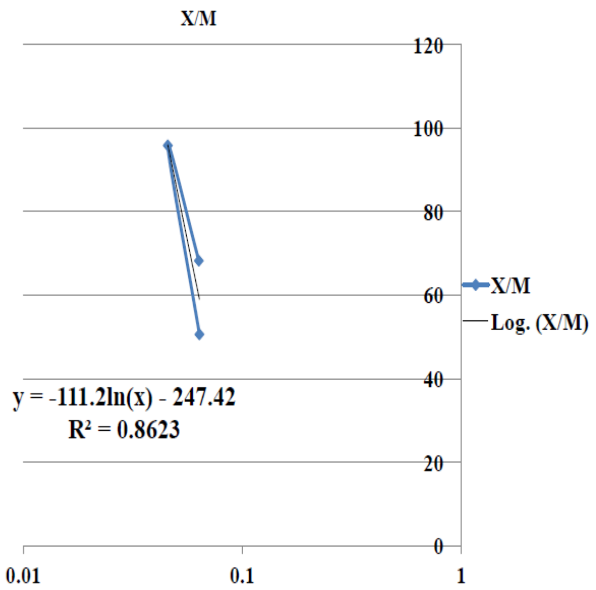
X/M								
	N1	N2	A	DF	B	S	M	X/M
1	0.1	0.1	1269.3	2.2	12.693	31.6	5.6690	68.24531
	0.1	0.1	1269.3	2.2	12.693	22.8	6.6003	95.84703
	0.1	0.1	1269.3	2.2	12.693	31.8	7.5310	50.63042
2	0.1	0.1	1269.3	2.2	12.693	34.6	4.2520	71.28618
	0.1	0.1	1269.3	2.2	12.693	31.4	4.9500	79.28638
	0.1	0.1	1269.3	2.2	12.693	29	5.6480	81.35386
	0.1	0.1	1269.3	2.2	12.693	30	2.8340	152.2802
	0.1	0.1	1269.3	2.2	12.693	30.6	3.3001	125.6954
	0.1	0.1	1269.3	2.2	12.693	30.8	3.7650	108.6912

Table 7.6: Calculations for the x axis of graph

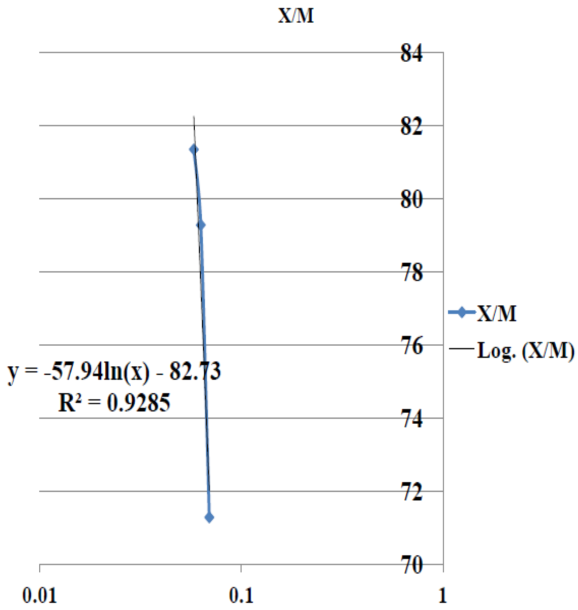
C				
	N1	S	F	C
1	0.1	31.6	50	0.0632
	0.1	22.8	50	0.0456
	0.1	31.8	50	0.0636
2	0.1	34.6	50	0.0692
	0.1	31.4	50	0.0628
	0.1	29	50	0.0580
3	0.1	30	50	0.0600
	0.1	30.6	50	0.0612
	0.1	30.8	50	0.0616

7.7.3 Graphical Representation

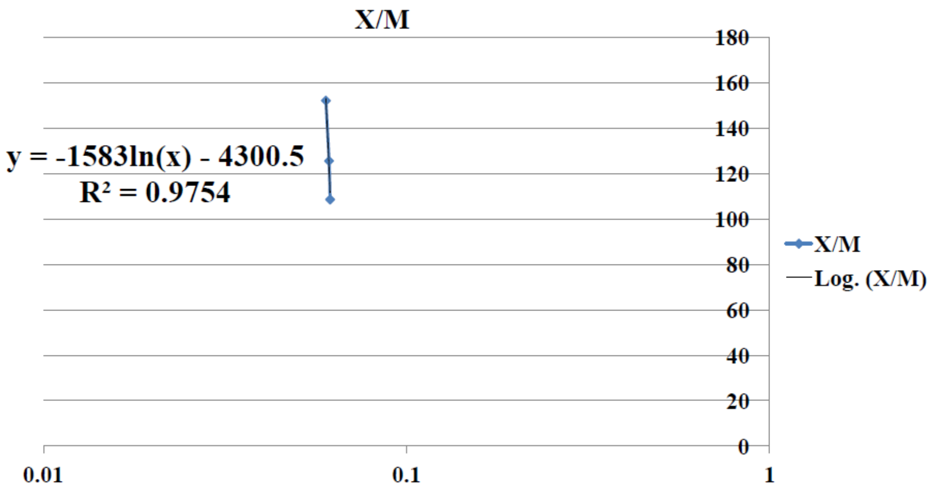
The graph shown in fig.7.3 is the graphical representation for iodine value test. It is obtained by plotting X/M (as shown in table 7.5) on X-axis and C (as shown in table 7.6) on Y-axis.



Set 1



Set 2



Set 3

Fig.7.3 Graphical representation for the iodine test 2

7.7.4 Results from Graph

Iodine Value of Biochar

- SET 1

  R^2=0.8623

  y=-111.2ln(x)-247.42=-111.2 ln(0.02)-247.42=187.5969

- SET 2

  R^2=0.9285

  y=-57.94ln(x)-82.73=-57.94 ln(0.02)-82.73=143.9326

- SET 3

  R^2=0.9754

  y=-1583ln(x)-4300.5=-1583 ln(0.02)-4300.5=1892.232

7.7.5 Inference

The iodine value exhibited by the CSBC indicates a lower degree of carbonaceous surface adsorption sites. Hence, this BC shows a reduced capacity for adsorbing contaminants. Therefore the CSBC may have limited effectiveness in applications requiring high adsorption or filtration capabilities.

CHAPTER 8

PREPARATION OF SYNTHETIC SAMPLE

8.1 GENERAL

Effluent samples can vary significantly in composition and quality depending on the source and time of sampling. By preparing synthetic water samples, specific contaminants and their concentrations can be precisely controlled, allowing for consistent and repeatable testing and treatment evaluations. This control is essential for research, development, and optimization of treatment processes.

8.2 PREPARATION OF SYNTHETIC PHOSPHATE WATER

8.2.1 General

Synthetic phosphate water is a solution containing inorganic phosphate salts and is commonly used in biological and chemical research. Here's how you can prepare synthetic phosphate water:

8.2.2 Materials

Sodium phosphate monobasic (NaH_2PO_4)

Sodium phosphate dibasic (Na_2HPO_4)

Distilled or deionized water

Graduated cylinder or volumetric flask

Stirring rod

8.2.3 Procedure

- Calculate the desired concentration of phosphate in the solution. For example, if you want to prepare a 0.1 M solution of phosphate, you will need to dissolve 1g of Na_2HPO_4 and 1g of NaH_2PO_4 in 1 litre of water.
- Weigh out the required amount of NaH_2PO_4 and Na_2HPO_4 using a balance and transfer them into a clean, dry glass beaker.
- Add a small amount of water (about 100 mL) to the beaker and stir the mixture with a stirring rod until the salts are completely dissolved.

- Transfer the solution to a graduated cylinder or volumetric flask, and add enough water to make up the final volume. For example, if you want to prepare 1 litre of solution, add water to the 1 litre mark.
- Stir the solution thoroughly to ensure that the salts are evenly distributed.

8.3 PREPARATION OF SYNTHETIC NITRATE WATER

8.3.1 General

It is not recommended to intentionally prepare synthetic nitrate-containing water as nitrates can have harmful effects on human health in high concentrations. However, if you need to prepare a nitrate-containing solution for laboratory purposes, here are the steps:

8.3.2 Materials

Distilled water
Potassium nitrate (KNO_3)
Measuring cylinder or beaker
Stirring rod

8.3.3 Procedure

- Measure the required volume of distilled water using a measuring cylinder or beaker.
- Weigh the appropriate amount of potassium nitrate (KNO_3) needed to achieve the desired concentration.
- Add the KNO_3 to the distilled water and stir using a stirring rod until it dissolves completely.
- Measure the concentration of the nitrate-containing water.

CHAPTER 9

BATCH AND COLUMN EXPERIMENTS

9.1 BATCH EXPERIMENT

9.1.1 General

Batch experiments, also known as static systems, are carried out by adding certain amount of solid into solution containing specific concentration of contaminants with a specific solid/liquid (S/L) ratio. These mixtures are vigorously stirred or shaken during the entire reaction time. The concentration of contaminant in solution is monitored and its change is thus regarded as the amount of contaminant to be partitioned onto solid. The merit of the batch approach lies in that it does not require much space of experiment apparatus while all variables of interest could be obtained experimentally. A batch adsorption method using biochar is a common approach for wastewater treatment. In this method, biochar is added to a batch of wastewater and allowed to interact with the contaminants present in the water. The biochar acts as an adsorbent, binding the contaminants onto its surface through various physical and chemical interactions. The effectiveness of a batch adsorption method using biochar can be influenced by several factors, including biochar properties, wastewater characteristics, contact time, agitation, and other operational parameters.

9.1.2 Apparatus Required

The following are the various apparatus required for the batch experiment.

- Magnetic stirrer
- Magnetic Beads
- Beakers
- Weighing machine
- Filter papers
- Funnel
- Conical flask
- China dish

9.1.3 Procedure

- Take synthetic water sample in a beaker.
- Add suitable different proportions (4gm, 8gm) of biochar to the beaker.
- Keep the beaker with the magnetic beads on a magnetic stirrer and fix 150 and 300 revolutions per minute for each proportions.
- Take small amount of sample at 30, 60, 90 and 120 minutes.
- Filter the sample on a filter paper and analyse the results.
- Stop the stirrer after 2 hours. The conduction of the experiment is shown in figure 9.1.

Fig.9.1 Conduction of batch experiments at 150 and 300 rpm

9.1.4 Result

i) Nitrate Batch Test

The obtained results of the batch experiment to check the nitrate removal efficiency of coconut shell biochars, powdered activated charcoal and granular activated charcoal are shown here.

1. Coconut Shell Biochar, 700°C at 2hrs 7mins

The graphical representation of the removal efficiency of the biochar at various proportions and at different revolutions per minute are shown in fig.9.2.

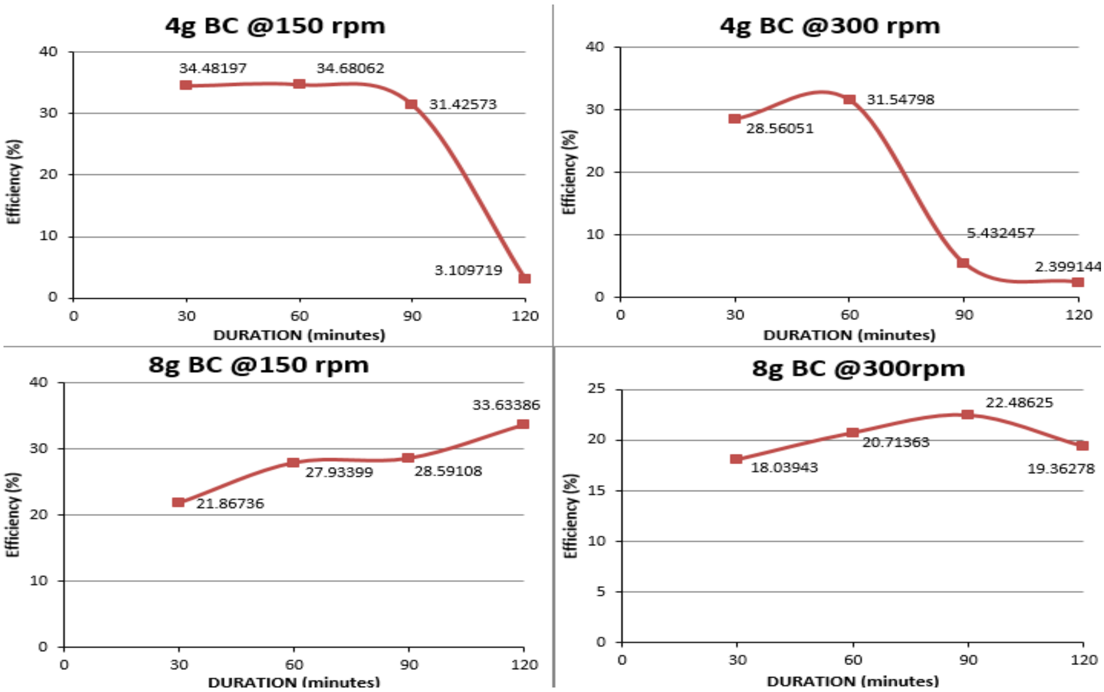


Fig.9.2 Duration v/s efficiency graphs of 700^0C CSBC on nitrate removal

2. Coconut Shell Biochar, 445°C at 2hrs 23mins

The graphical representation of the removal efficiency of the biochar at various proportions and at different revolutions per minute are shown in fig.9.3.

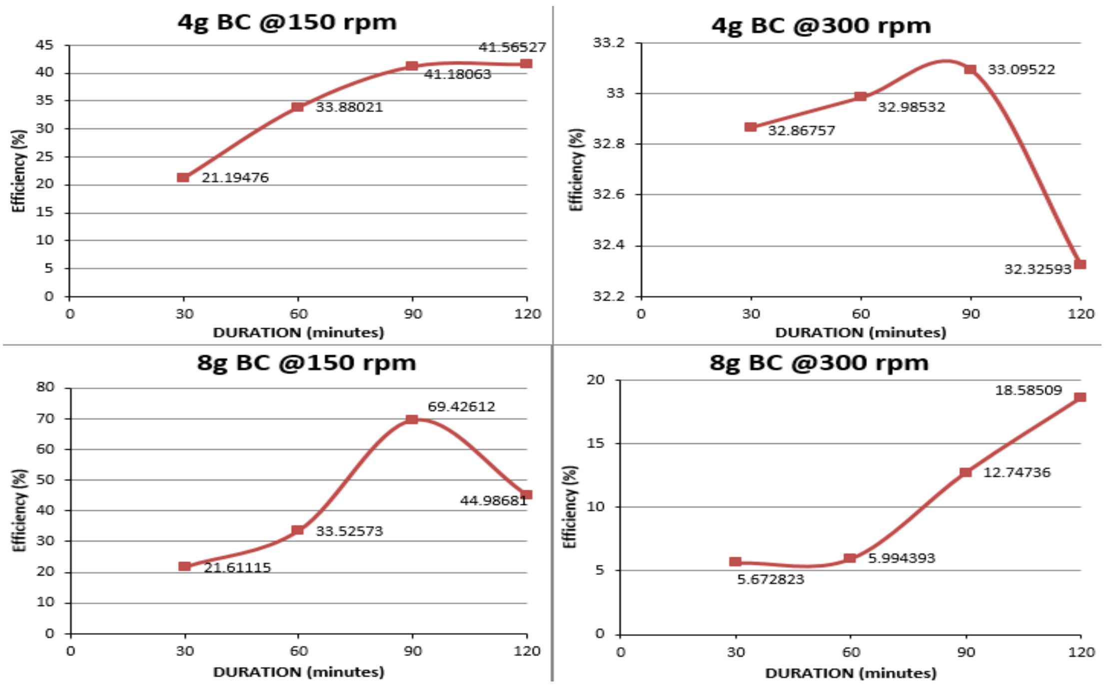


Fig.9.3 Duration v/s efficiency graphs of 445^0C CSBC on nitrate removal

3. Powdered activated charcoal

The graphical representation of the removal efficiency of the biochar at various proportions and at different revolutions per minute are shown in fig.9.4.

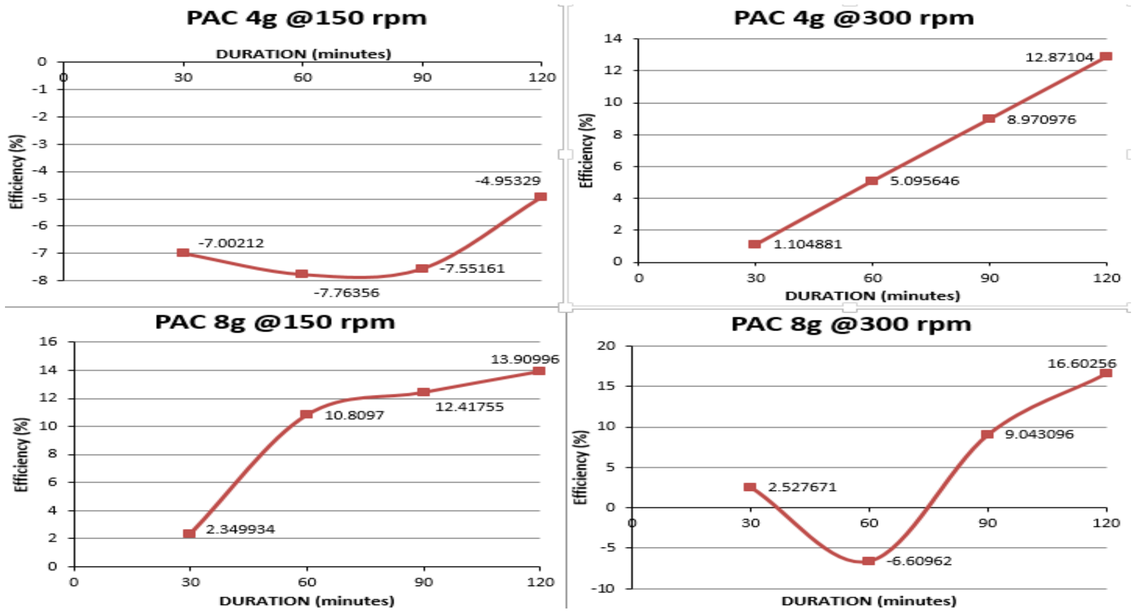


Fig.9.4 Duration v/s efficiency graphs of PAC on nitrate removal

4. Granular activated charcoal

The graphical representation of the removal efficiency of the biochar at various proportions and at different revolutions per minute are shown in fig.9.5.

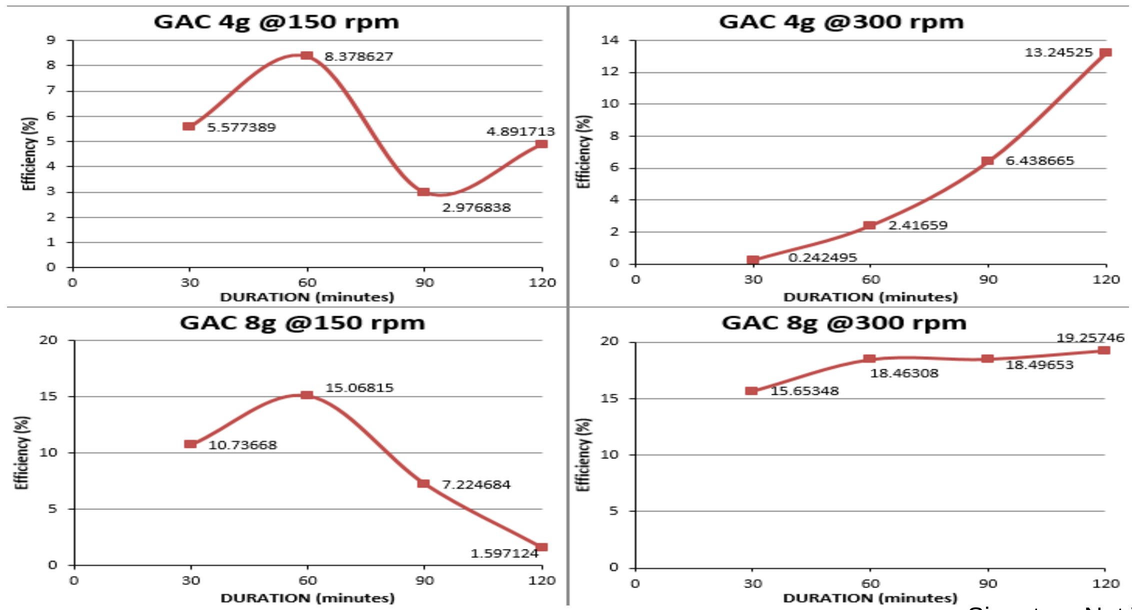


Fig.9.5 Duration v/s efficiency graphs of GAC on nitrate removal

9.1.5 Combination of Parameters

i) Duration v/s Efficiency

The comparison of duration v/s efficiency graph for the nitrate removal using various sorbents are given in fig. 9.6. The sorbents are 700^{0}C CSBC, 445^{0}C CSBC, PAC and GAC. The values at various revolutions per minute, contact periods and biochar dosages are compared here.

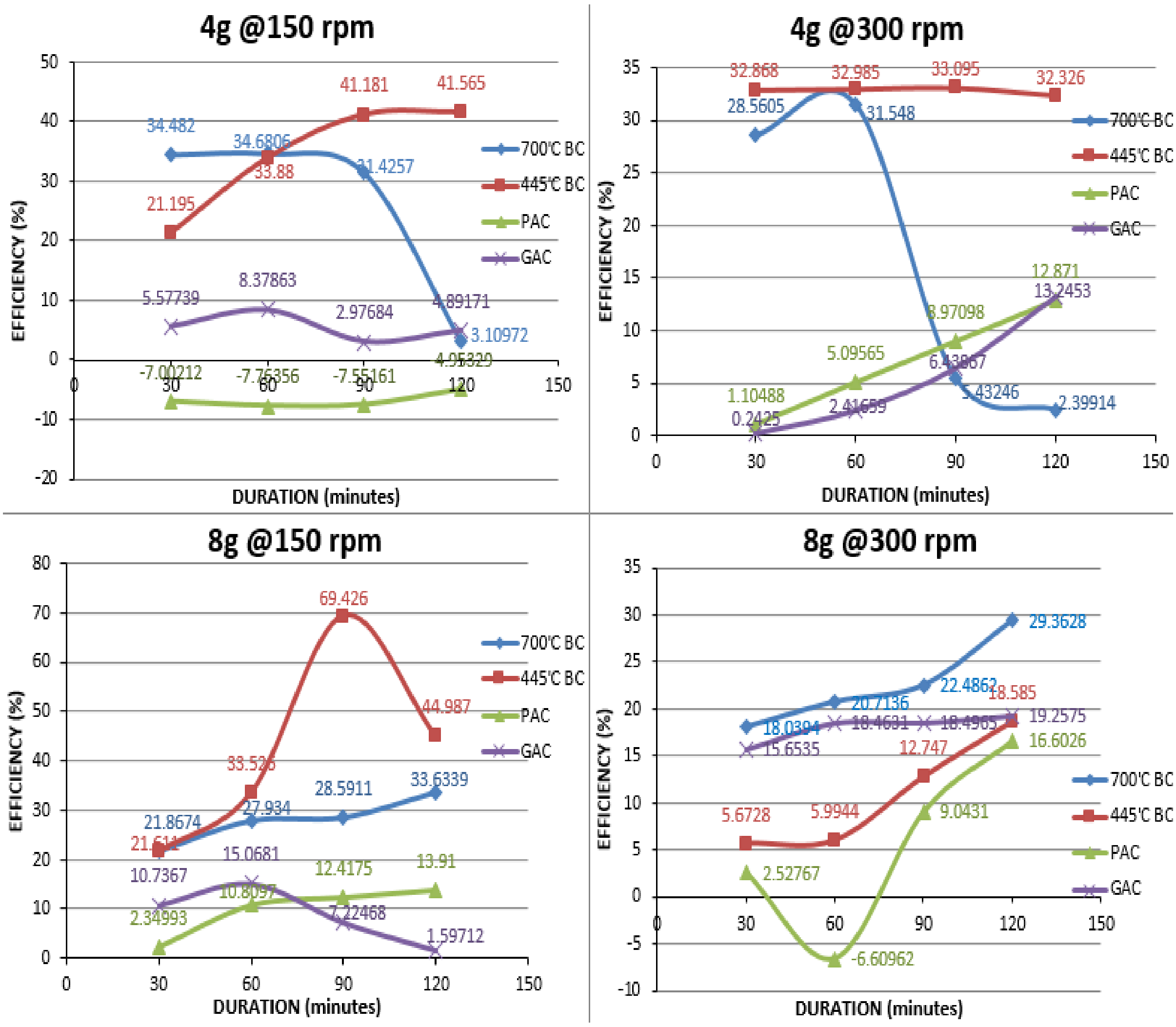


Fig.9.6 Duration v/s efficiency graphs of various sorbents for nitrate removal

ii) Duration v/s Change in pH

The comparison of duration v/s change in pH graph for the nitrate removal using various sorbents are given in fig. 9.7. The sorbents are 700^{0}C CSBC, 445^{0}C CSBC, PAC and GAC. The values at various revolutions per minute, contact periods and biochar dosages are compared here.

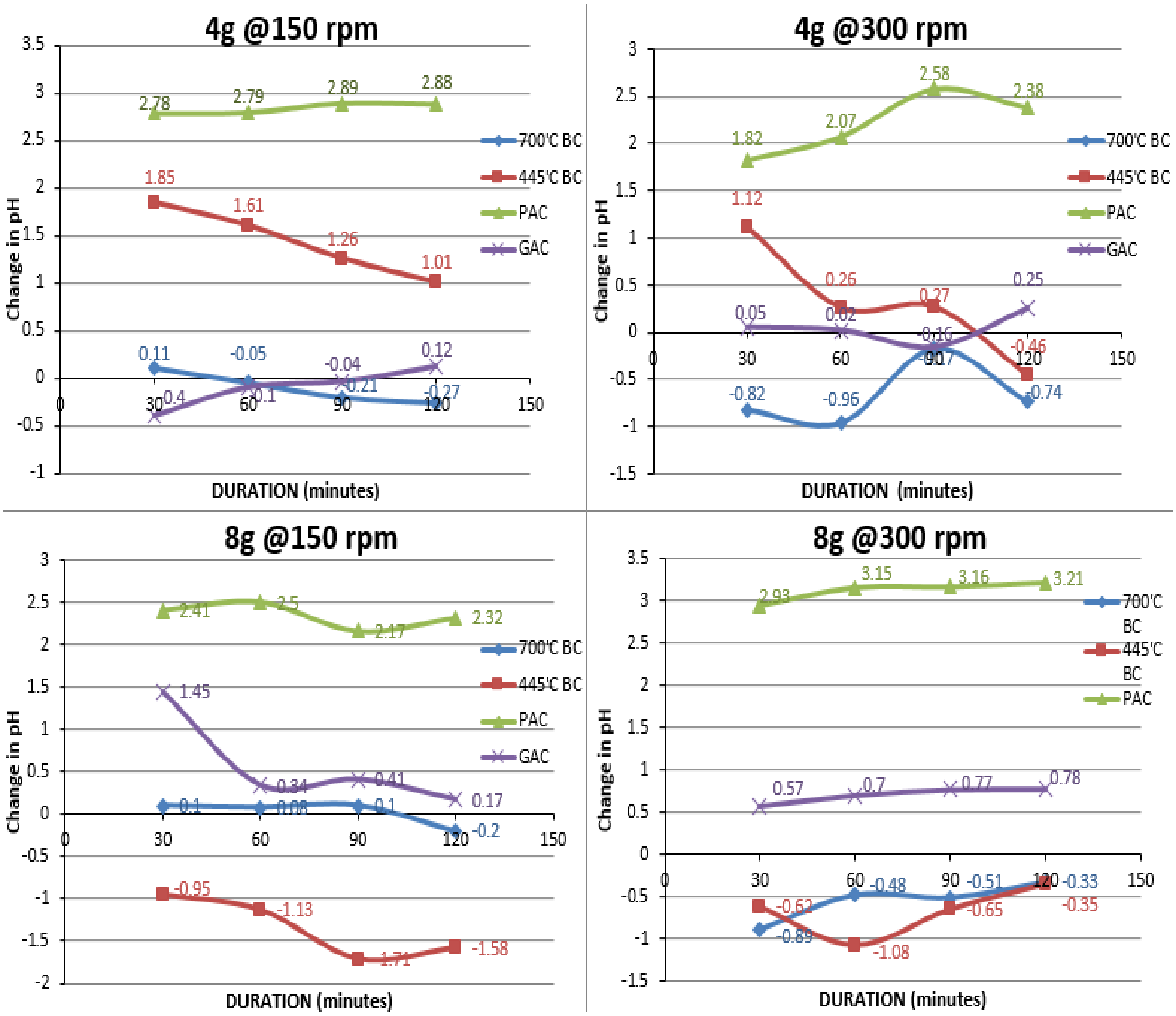


Fig.9.7 Duration v/s change in pH graphs of various sorbents for nitrate removal

9.1.6 Analysis of the Result

i) Effect of Dosage

Biochar has a porous structure that provides a large surface area for adsorption, allowing it to bind to pollutants such as heavy metals and chemical compounds. The results shows that higher dosages can result in greater adsorption capacity and improved removal rates.

ii) Effect of Contact Time

The contact time plays a crucial role in the effectiveness of the adsorption process and significantly affect the treatment efficiency. Initially, the adsorption rate is high as there are more available adsorption sites. Over time, the rate slows down as the concentration of the

adsorbate decreases in the wastewater. The adsorption process follows a typical pattern, starting with a rapid adsorption phase followed by a slower equilibrium phase.

iii) Effect of Revolutions per Minute

The number of revolutions influences the overall contaminant removal efficiency. Higher revolutions generate more turbulence and maintain the biochar particles in suspension, preventing settling or aggregation. Thus ensured a uniform contact between the biochar and the wastewater, enhancing adsorption efficiency. The biochar tends to settle quickly at 150 rpm, increasing the agitation to 300 rpm improved the overall effectiveness.

iv) Effect of pH

At lower pH levels, the biochar's surface becomes protonated, resulting in an increased positive charge. This enhanced positive charge can facilitate the electrostatic attraction between the biochar and the negatively charged nitrate ions, promoting adsorption. Therefore, the batch adsorption method using coconut shell biochar is expected to show higher nitrate removal efficiency at lower pH levels.

Conversely, at higher pH levels, the surface of the biochar becomes deprotonated, resulting in a decreased positive charge or even a negative charge. This change in surface charge reduces the electrostatic attraction between the biochar and the nitrate ions, potentially leading to a decrease in adsorption efficiency. Therefore, the batch adsorption method using coconut shell biochar may exhibit lower nitrate removal efficiency at higher pH levels.

The synthetic water treated with PAC and GAC shows high variation from initial pH, whereas much variations where not observed for synthetic water treated with CSBCs.

9.2 COLUMN EXPERIMENT

9.2.1 General

In chemistry, Column chromatography is a technique which is used to separate a single chemical compound from a mixture dissolved in a fluid. Column chromatography separates substances based on differential adsorption of compounds to the adsorbent as the compounds move through the column at different rates which allows them to get separated in fractions. This technique can be used on a small scale as well as large scale to purify materials that can

be used in future experiments. This method is a type of adsorption chromatography technique. Column absorption treatment using biochar offers a sustainable and cost-effective approach for removing various pollutants from water or liquid streams. Its versatility, combined with the renewable nature of biochar, makes it an attractive option for water treatment applications and environmental remediation.

9.2.2 Apparatus Required

- Glass column
- Mobile phase
- Stationary phase
- Filter paper
- Glass filter
- Sorbent
- Beakers
- Funnel
- Tray

9.2.3 Procedure

- Take a clean glass column.
- Keep the fine filter and the Whatman filter paper at the bottom of the glass column.
- Fill sorbents (700^0 C coconut shell biochar, 445^0C coconut shell biochar, powdered activated charcoal and granular activated charcoal) in the column at various bed heights of 0.5cm, 1cm, 1.5cm, 2cm and 2.5cm for different trials.
- Fill the top of the column with Whatman filter paper and a perforated glass filter.
- Feed the effluent sample from the top of the glass column and collect the effluent sample from the bottom. The schematic diagram and the conduction of column experiment are shown in fig.9.8.
- Collect the samples of each set of experiment and store it in a small volumetric flasks.
- The sample is undergone for tests for various parameters like pH and Chemical Oxygen Demand (COD).
- Determine the concentration of the effluent using UV-Visible Double Beam Spectrophotometer.

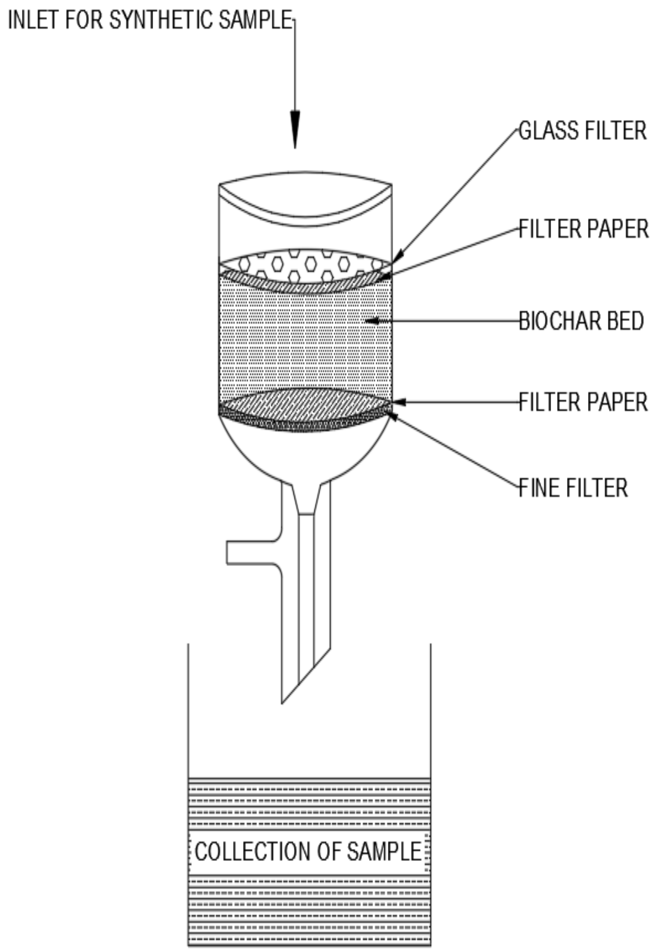


Fig. 9.8 Schematic diagram and conduction of column test

9.2.4 Result

i) Nitrate column experiment

The obtained results of the column experiment to check the nitrate removal efficiency of coconut shell biochars, powdered activated charcoal and granular activated charcoal are shown in figures.

1. Coconut Shell Biochar, 700°C at 2hrs 7mins

CSBC pyrolyzed at 700^0C were used to remove nitrate from the synthetic sample and various results were obtained. Fig.9.9 shows the bed height v/s concentration graph for nitrate removal using 700^0 C CSBC. Fig.9.10 shows the bed height v/s pH graph, bed height v/s efficiency graph is given in fig.9.11 and bed height v/s COD graph is shown in fig.9.12.

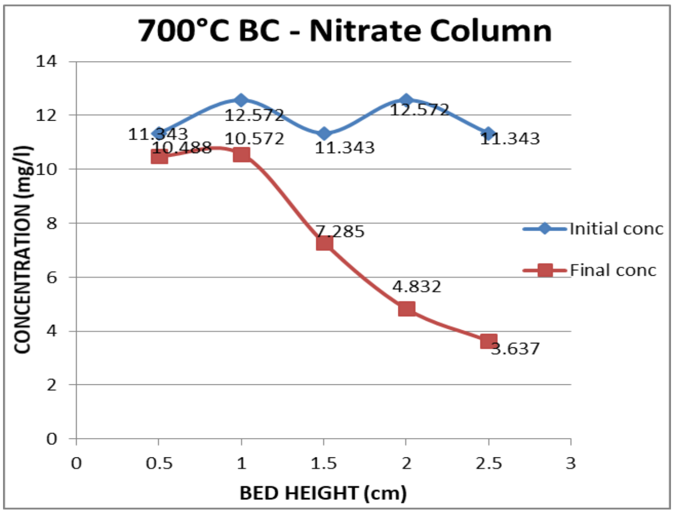


Fig.9.9 Bed height v/s concentration graph for nitrate removal using 700^0 C CSBC

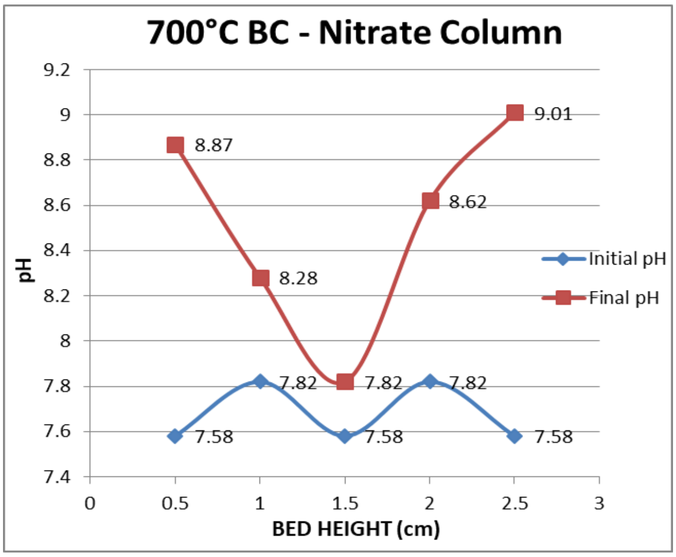


Fig.9.10 Bed height v/s pH graph for nitrate removal using 700^{0}C CSBC

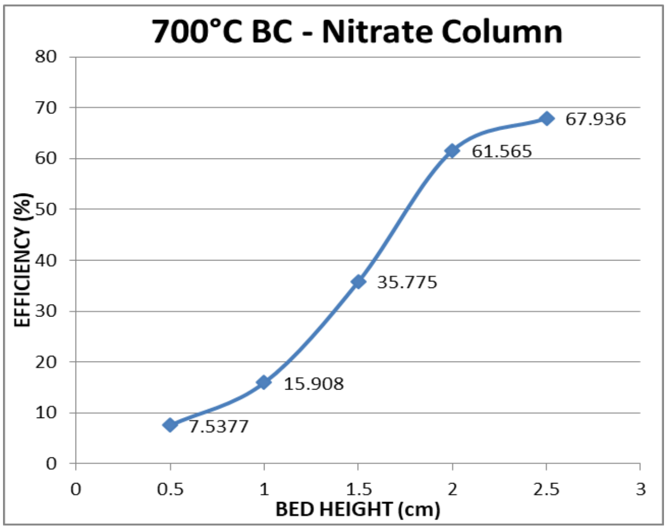


Fig.9.11 Bed height v/s efficiency graph for nitrate removal using 700^{0}C CSBC

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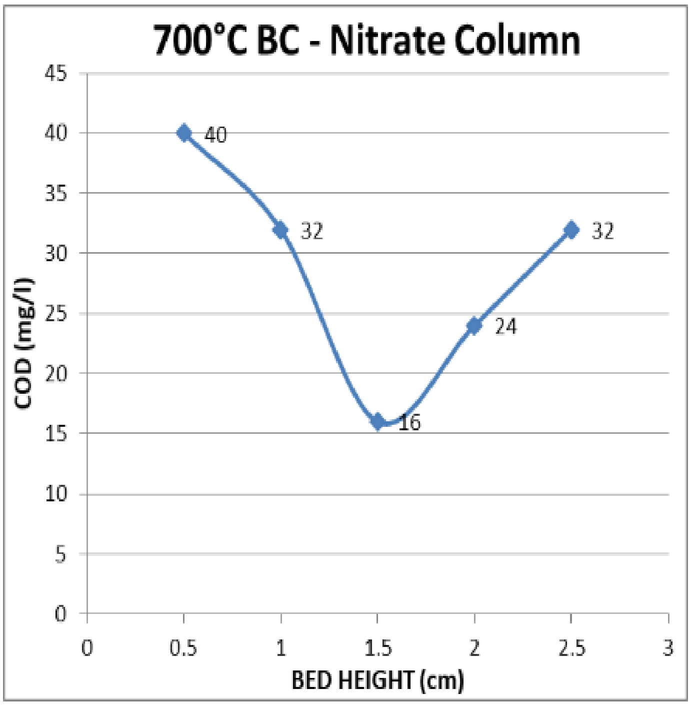

Fig.9.12 Bed height v/s COD graph for nitrate removal using 700^0C CSBC

2. Coconut Shell Biochar, 445°C at 2hrs 7mins

CSBC pyrolyzed at 445^0C were used to remove nitrate from the synthetic sample and various results were obtained. Fig.9.13 shows the bed height v/s concentration graph. Fig.9.14 shows the bed height v/s pH graph and bed height v/s efficiency graph is given in fig.9.15.

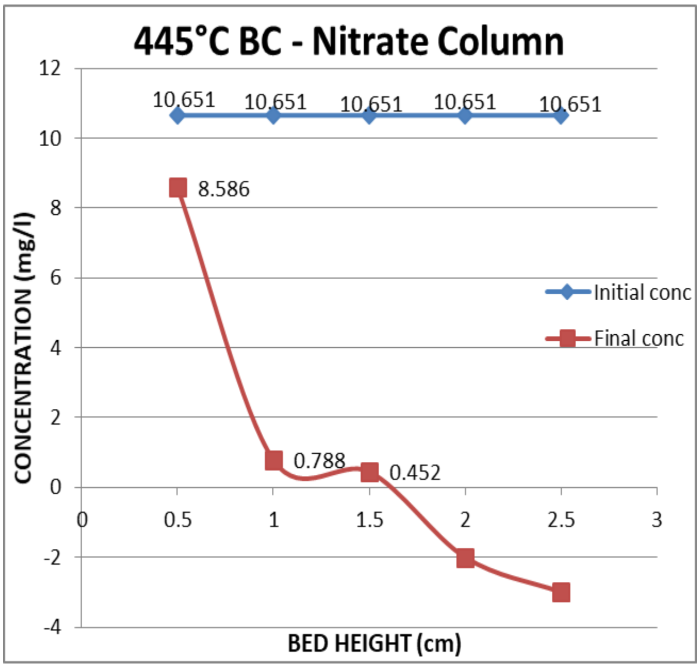

Fig.9.13 Bed height v/s concentration graph for nitrate removal using 445^0C CSBC

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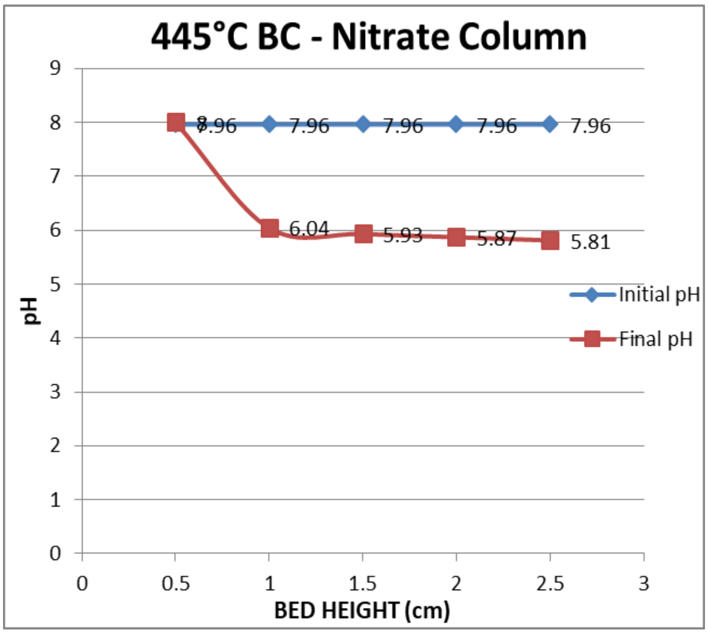

Fig.9.14 Bed height v/s pH graph for nitrate removal using 445^{0}C CSBC

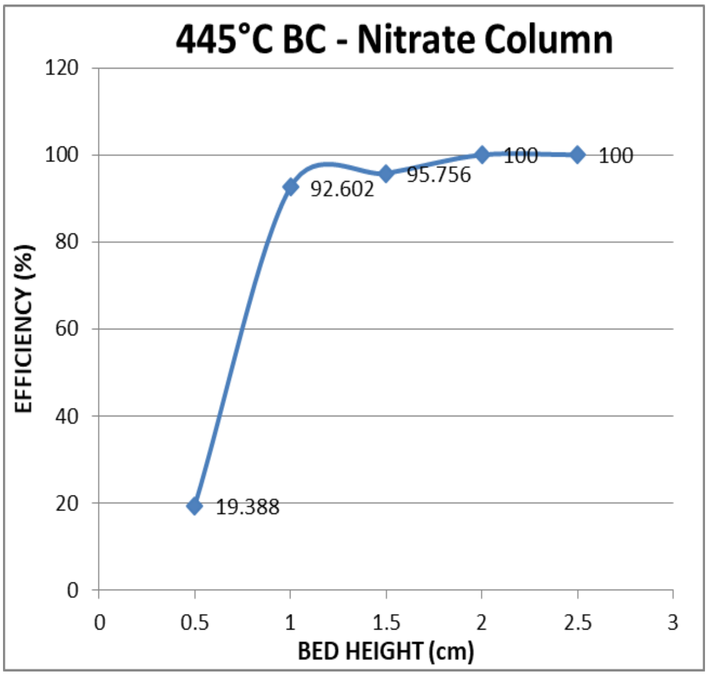

Fig.9.15 Bed height v/s efficiency graph for nitrate removal using 445^{0}C CSBC

3. Powdered activated charcoal

Powdered activated charcoal were used to remove nitrate from the synthetic sample and various results were obtained. Fig.9.16 shows the bed height v/s concentration graph. Fig.9.17 shows the bed height v/s pH graph, bed height v/s efficiency graph is given in fig.9.18 and bed height v/s COD graph is shown in fig.9.19.

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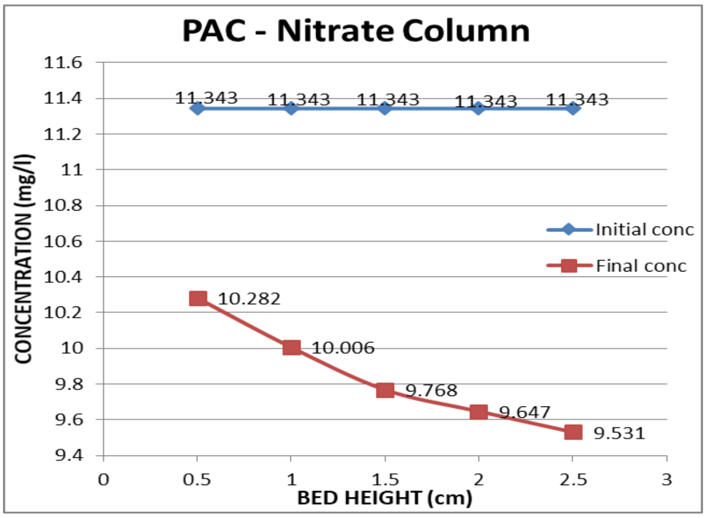

Fig.9.16 Bed height v/s concentration graph for nitrate removal using PAC

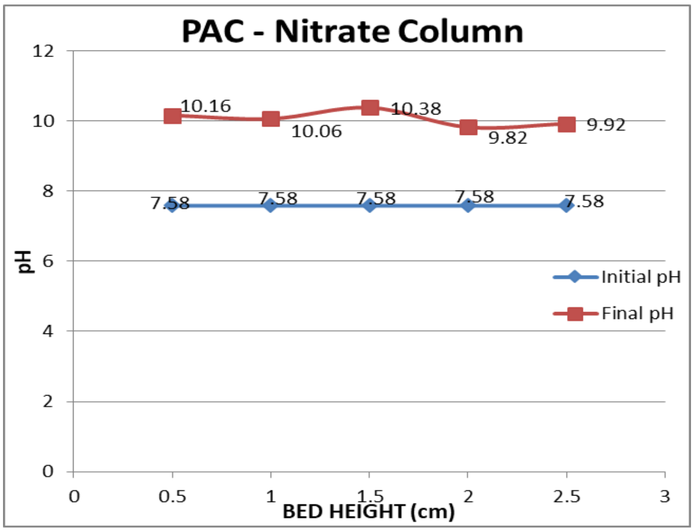

Fig.9.17 Bed height v/s pH graph for nitrate removal using PAC

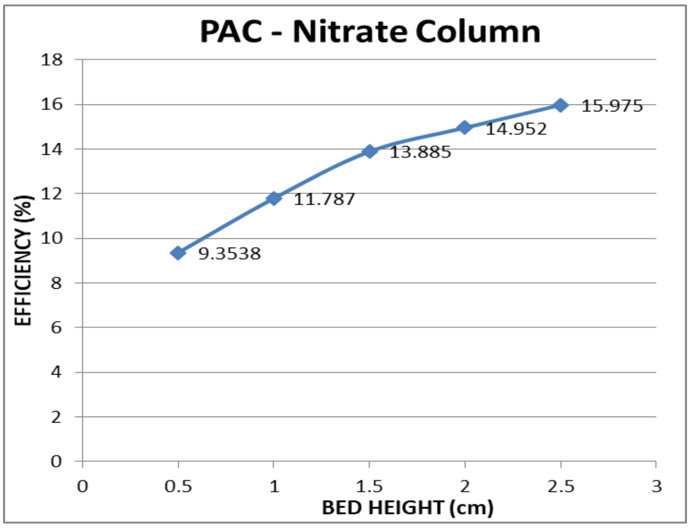

Fig.9.18 Bed height v/s efficiency graph for nitrate removal using PAC

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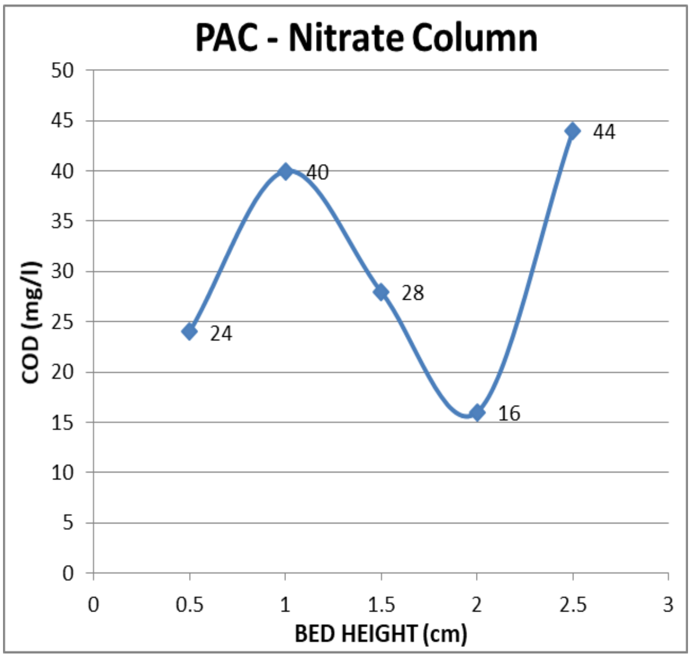

Fig.9.19 Bed height v/s COD graph for nitrate removal using PAC

4. Granular activated charcoal

Granular activated charcoal were used to remove nitrate from the synthetic sample and various results were obtained. Fig.9.20 shows the bed height v/s concentration graph. Fig.9.21 shows the bed height v/s pH graph and bed height v/s efficiency graph is given in fig.9.22.

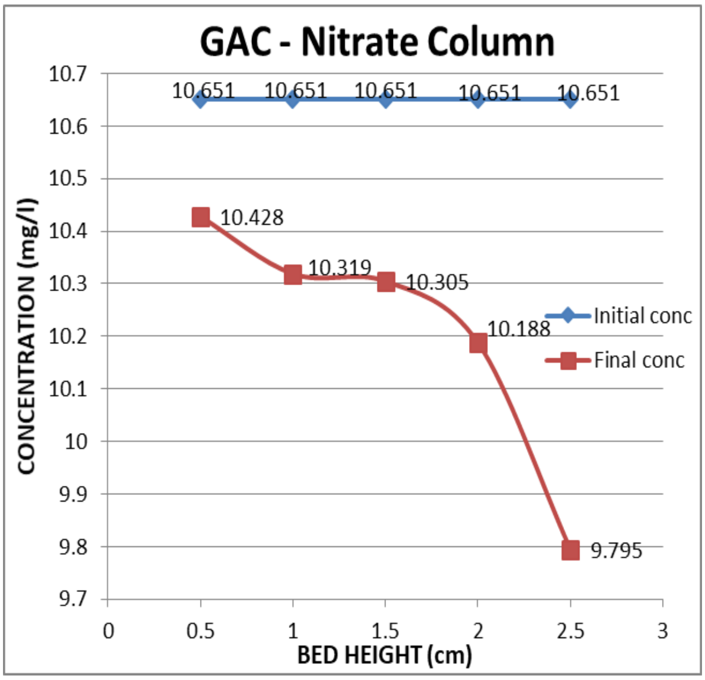

Fig.9.20 Bed height v/s concentration graph for nitrate removal using GAC

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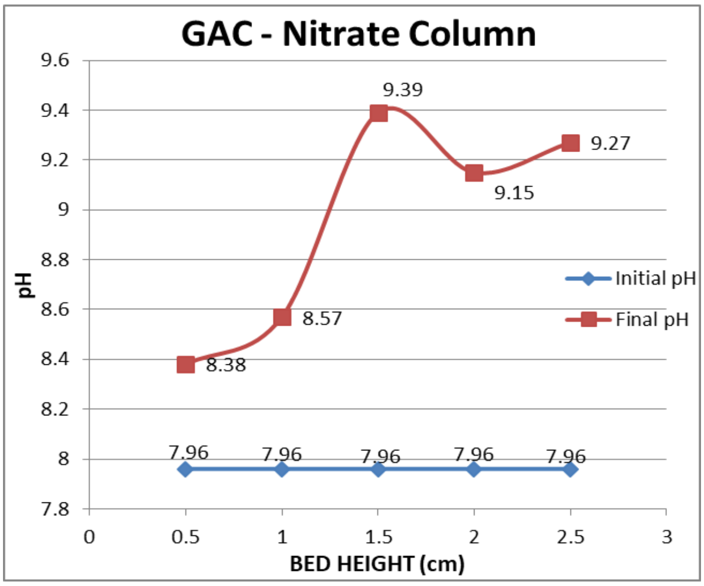

Fig.9.21 Bed height v/s pH graph for nitrate removal using GAC

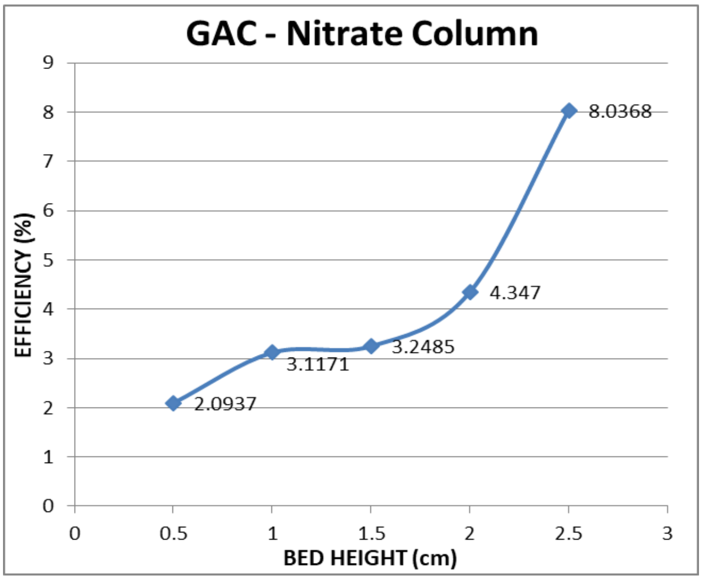

Fig.9.22 Bed height v/s efficiency graph for nitrate removal using GAC

ii) Phosphate Column Experiment

The obtained results of the column experiment to check the phosphate removal efficiency of coconut shell biochars, powdered activated charcoal carbon and granular activated charcoal are shown in figures.

1. Coconut Shell Biochar, 700°C at 2hrs 23mins

CSBC pyrolyzed at 700^{0}C were used to remove phosphate from the synthetic sample and various results were obtained. Fig.9.23 shows the bed height v/s concentration graph. Fig.9.24 shows the bed height v/s pH graph and bed height v/s efficiency graph is given in fig.

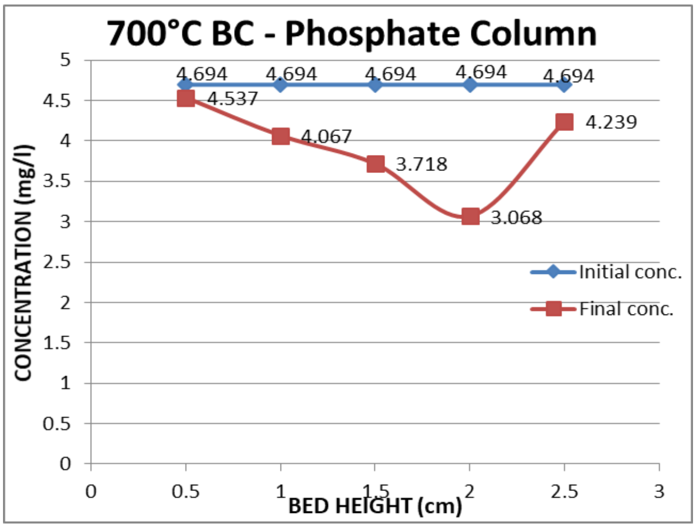

Fig.9.23 Bed height v/s concentration graph for phosphate removal using 700^{0}C CSBC

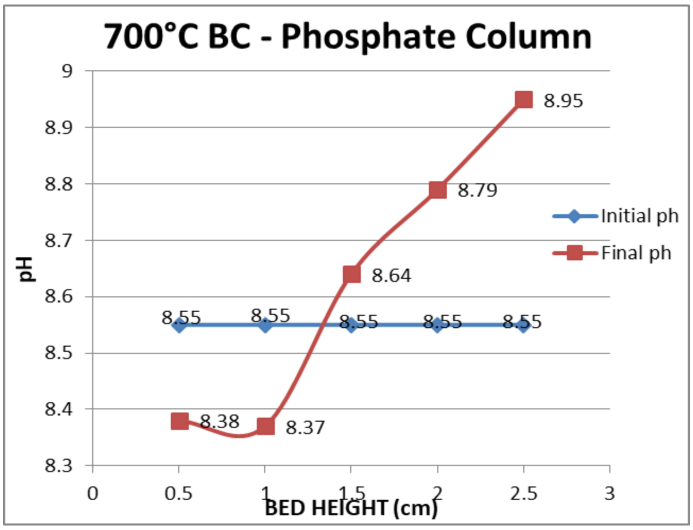

Fig.9.24 Bed height v/s pH graph for phosphate removal using 700^{0}C CSBC

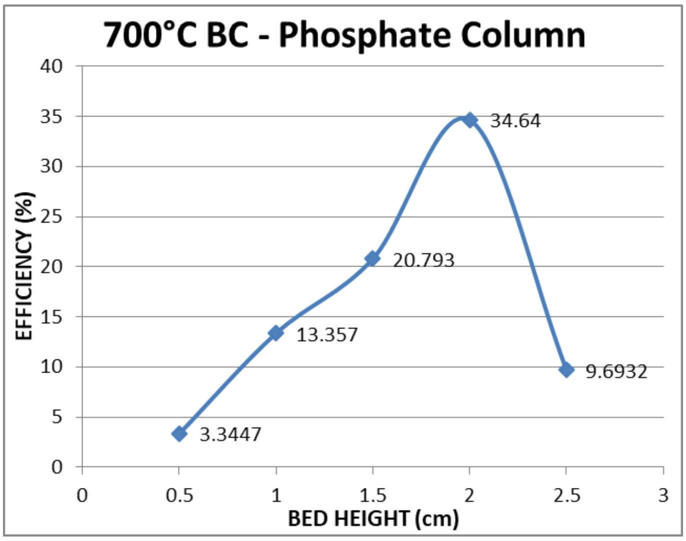

Fig.9.25 Bed height v/s efficiency graph for phosphate removal using 700^{0}C CSBC

2. Coconut Shell Biochar, 445°C at 2hrs 7mins

CSBC pyrolyzed at 445^{0}C were used to remove phosphate from the synthetic sample and various results were obtained. Fig.9.26 shows the bed height v/s concentration graph. Fig.9.27 shows the bed height v/s pH graph and bed height v/s efficiency graph is given in fig.9.28.

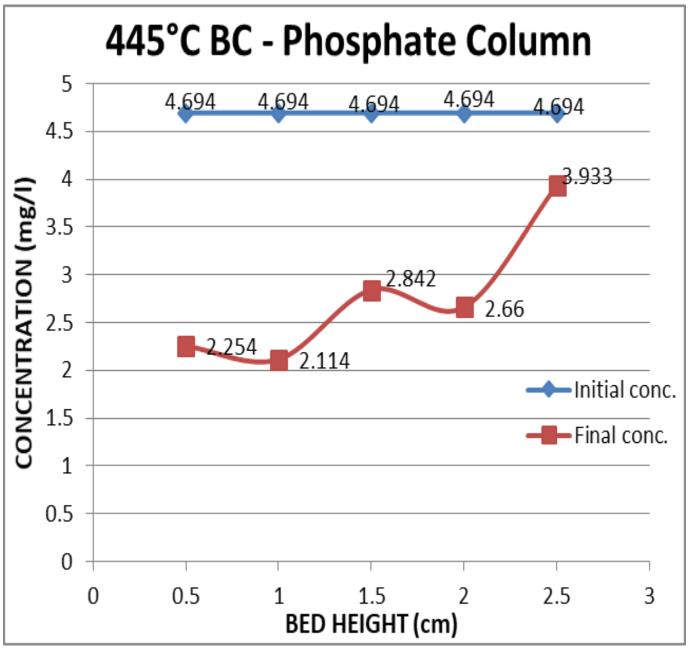

Fig.9.26 Bed height v/s concentration graph for phosphate removal using 445^{0}C CSBC

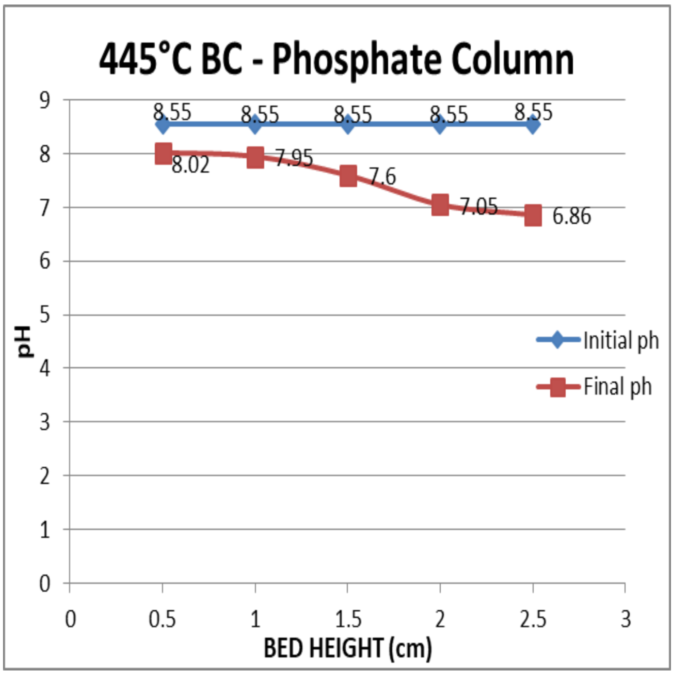

Fig.9.27 Bed height v/s pH graph for phosphate removal using 445^{0}C CSBC

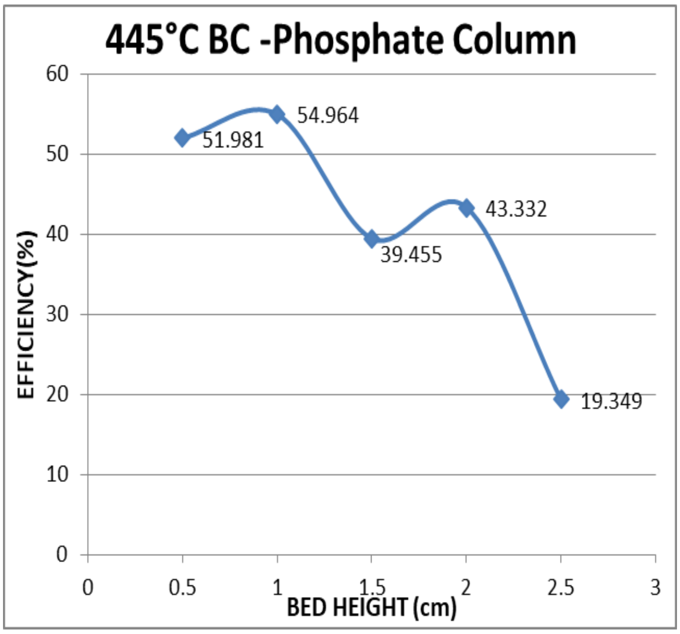

Fig.9.28 Bed height v/s efficiency graph for phosphate removal using 445^{0}C CSBC

3. Powdered activated charcoal

PAC were used to remove phosphate from the synthetic sample and various results were obtained. Fig.9.29 shows the bed height v/s concentration graph. Fig.9.30 shows the bed height v/s pH graph and bed height v/s efficiency graph is given in fig.9.31.

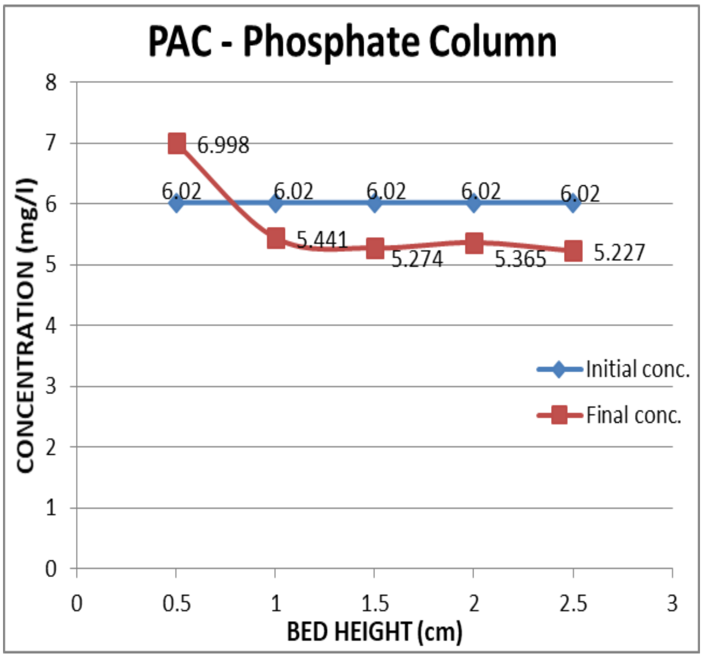

Fig.9.29 Bed height v/s concentration graph for phosphate removal using PAC

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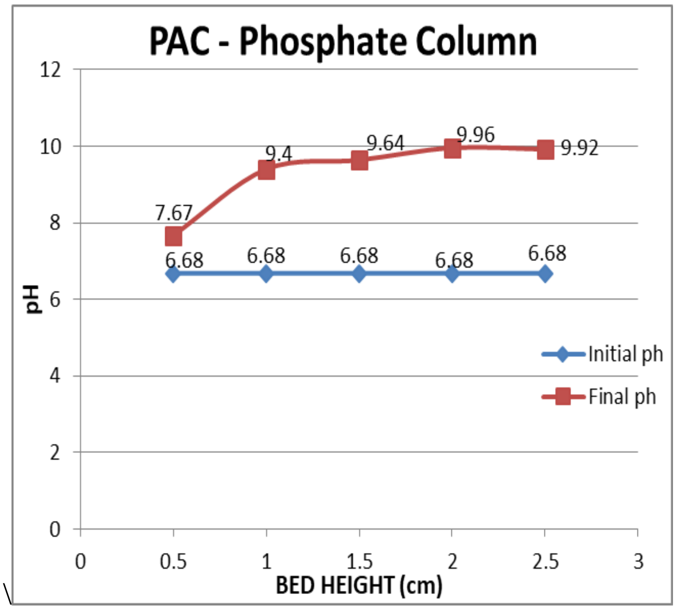

Fig.9.30 Bed height v/s pH graph for phosphate removal using PAC

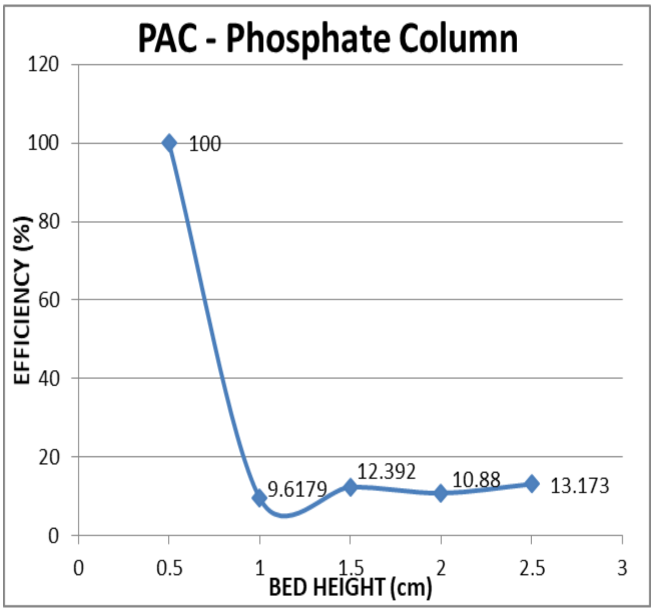

Fig.9.31 Bed height v/s efficiency graph for phosphate removal using PAC

4. Granular activated charcoal

GAC were used to remove phosphate from the synthetic sample and various results were obtained. Fig.9.32 shows the bed height v/s concentration graph. Fig.9.33 shows the bed height v/s pH graph and bed height v/s efficiency graph is given in fig.9.34.

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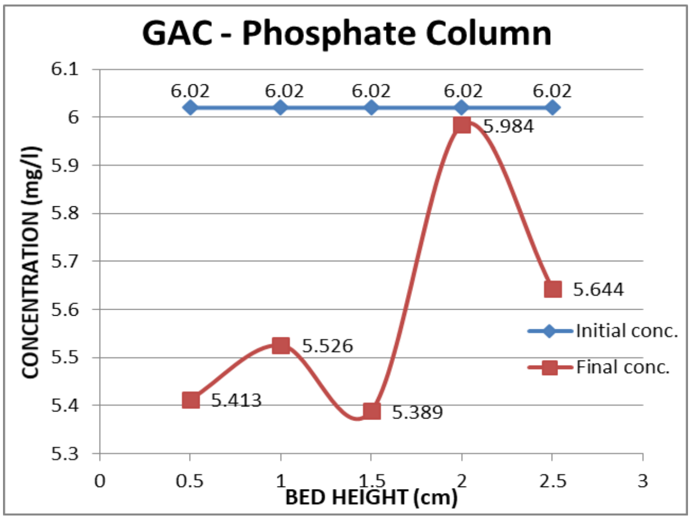

Fig.9.32 Bed height v/s concentration graph for phosphate removal using GAC

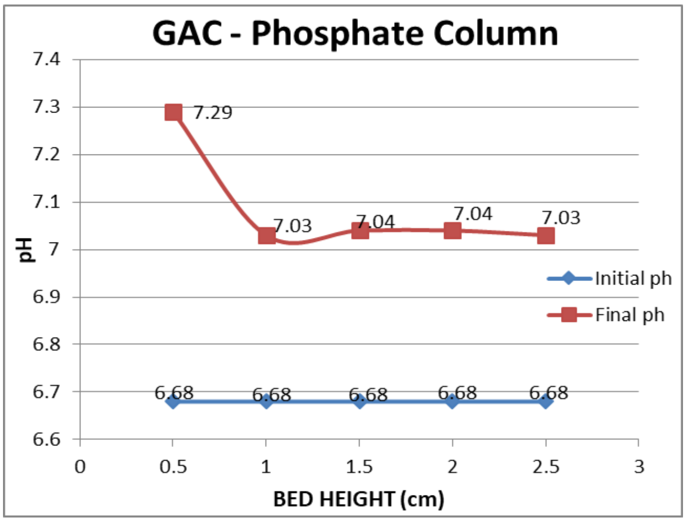

Fig.9.33 Bed height v/s pH graph for phosphate removal using GAC

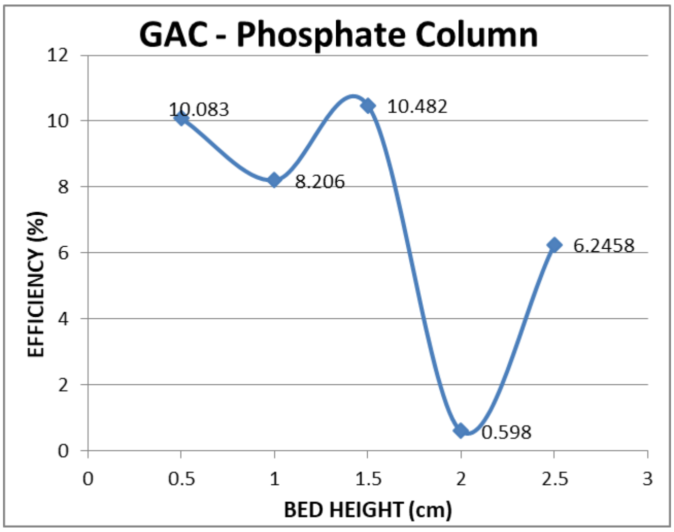

Fig.9.34 Bed height v/s efficiency graph for phosphate removal using GAC

9.2.5 Combination of Parameters

i) Bed Height v/s Efficiency

The comparison of bed height v/s efficiency graph for the nitrate removal and phosphate removal using various sorbents are given in fig. 9.35 and fig. 9.36 respectively. The sorbents are 700^{0}C CSBC, 445^{0}C CSBC, PAC and GAC. The values at various bed heights are compared here.

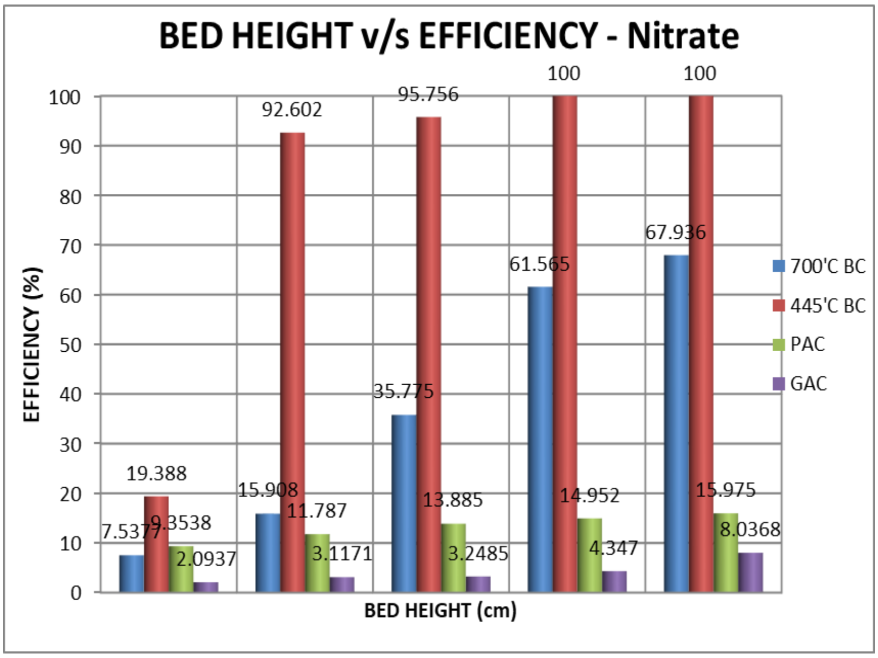

Fig.9.35 Bed height v/s efficiency graph of various sorbents for nitrate removal

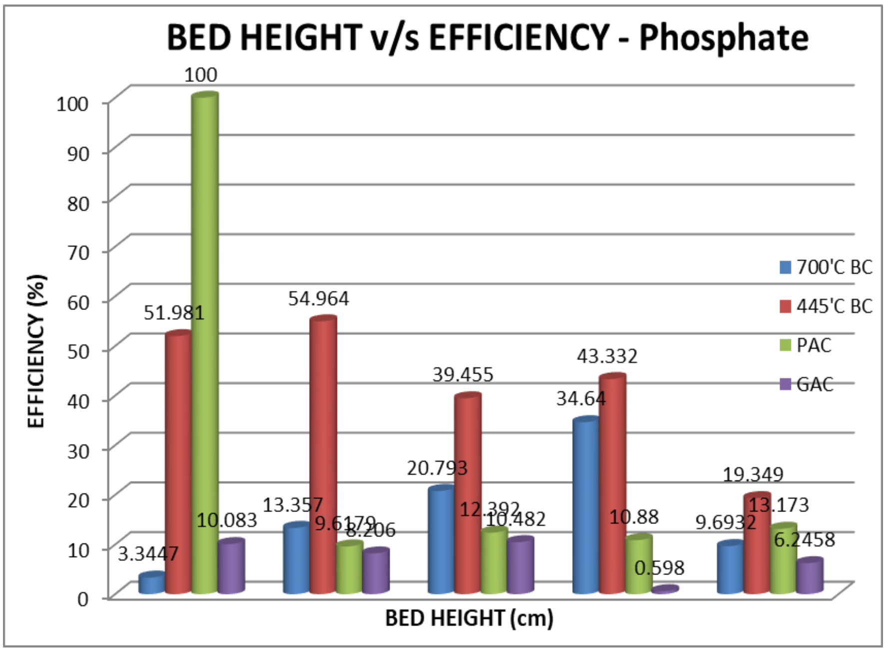

Fig.9.36 Bed height v/s efficiency graph of various sorbents for phosphate removal

ii) Bed Height v/s Change in pH

The comparison of bed height v/s change in pH graph for the nitrate removal and phosphate removal using various sorbents are given in fig. 9.37 and fig. 9.38 respectively. The sorbents are 700^{0}C CSBC, 445^{0}C CSBC, PAC and GAC. The values at various bed heights are compared here.

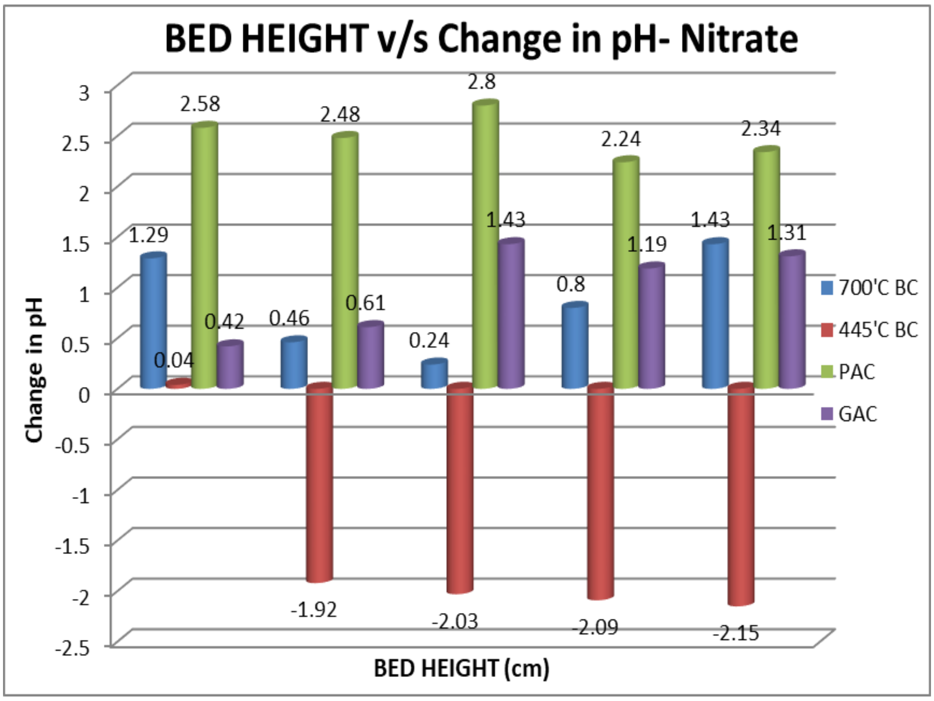

Fig.9.37 Bed height v/s change in pH graph of various sorbents for nitrate removal

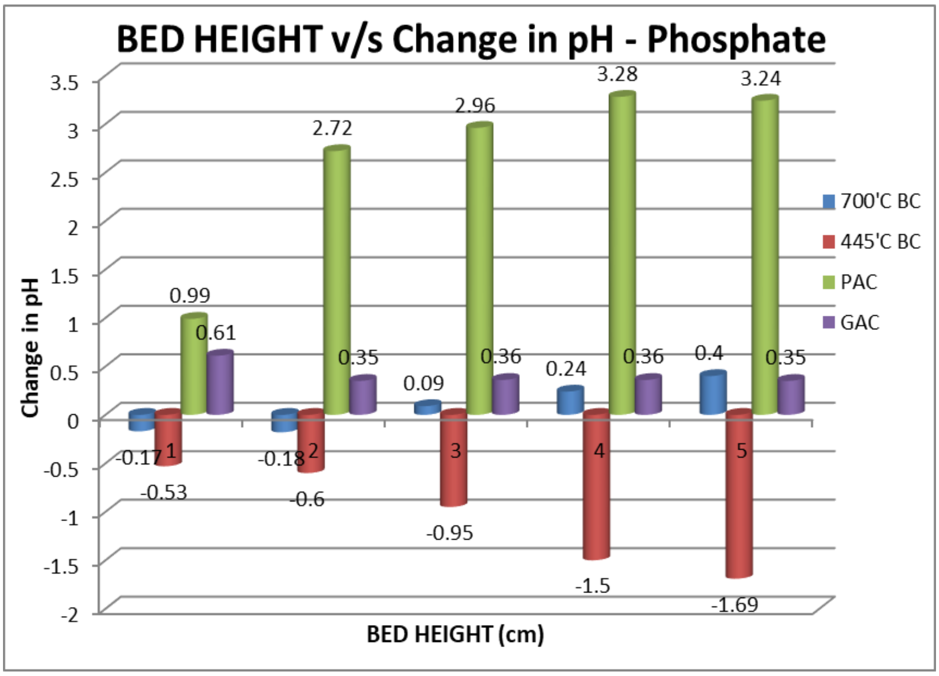

Fig.9.38 Bed height v/s Change in pH graph of various sorbents for phosphate removal

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9.2.6 Analysis of the Result

i) Effect of Bed Height

The bed height directly affects the adsorption capacity of the biochar column. A greater bed height provides a larger surface area for adsorption, allowing more contaminants to come into contact with the biochar. As a result, a taller biochar bed accommodate a higher concentration of contaminants and potentially provide a higher adsorption capacity as compared to that of small bed height.

ii) Effect of pH

The pH of the solution plays a significant role in the column absorption treatment using biochar for the removal of nitrate and phosphate from contaminated water. The adsorption capacity of biochar for nitrate and phosphate ions can vary with pH. In general, at a neutral pH, biochar exhibits good adsorption capacity for both nitrate and phosphate. However, as the pH deviates from neutral, the adsorption capacity is affected.

The synthetic water treated with PAC and GAC shows high variation from initial pH, whereas much variations where not observed for synthetic water treated with CSBCs.

9.3 FUTURE SCOPE

Although the project's timeline may pose limitations on its comprehensive completion, it is planned to conduct tests on two different methods of contaminant removal: batch adsorption and column absorption treatment using water hyacinth and wood chips biochars. The primary focus of these experiments is to assess the efficiency of these materials in removing contaminants, specifically nitrate, phosphate and cadmium from water sources.

In the batch adsorption method, controlled laboratory tests will be conducted by introducing predetermined quantities of water hyacinth and wood chips biochar to water samples containing the targeted contaminants. The samples will be agitated and allowed to interact for a specified duration to facilitate adsorption. Subsequently, the concentrations of the contaminants in the water will be measured before and after the adsorption process to evaluate the effectiveness of the materials.

In addition to the batch adsorption method, a column absorption treatment method will be implemented. This method involves passing contaminated water through columns packed with water hyacinth and wood chips biochar. The water will flow through the column at a predetermined rate, allowing the materials to adsorb the targeted contaminants. Samples collected at various stages of the column will be analyzed to determine the extent of contaminant removal.

While the complete assessment of these methods for the removal of nitrate, phosphate, and cadmium is not guaranteed due to time constraints, the project aims to provide valuable insights into the effectiveness of water hyacinth and wood chips biochar as potential solutions for water contamination. These findings can serve as a basis for further research and development in this field.

CHAPTER 10

CONCLUSION

In conclusion, the project focused on evaluating the removal efficiency of coconut shell biochar for nitrate and phosphate contaminants in contaminated water. The project demonstrated that coconut shell biochar has the potential to effectively remove nitrate, while it is less effective in removing phosphate from contaminated water. The biochar exhibited significant adsorption capacity for these contaminants due to its porous structure and high surface area. The project found that the removal efficiency of nitrate and phosphate was influenced by various factors such as contact time, revolutions per minute, initial contaminant concentration, bed height and biochar dosage. Overall, the project contributes to the understanding of coconut shell biochar as a promising adsorbent for the removal of nitrate from water. Through our extensive experimentation and analysis, we have determined that the removal efficiency of nitrate is more effective compared to phosphate using coconut shell biochar.

- Effects on nitrate column method

A taller biochar bed accommodate a higher concentration of contaminants and potentially provide a higher adsorption capacity as compared to that of small bed height. The synthetic water treated with PAC and GAC shows high variation from initial pH, whereas much variations where not observed for synthetic water treated with CSBCs.

- Effects on phosphate column method

CSBC doesn't show much effectiveness for phosphate removal. This may be due to the presence some other phosphate compounds present in the coconut shell biochar.

- Effects on nitrate batch method

Higher revolutions enhances the adsorption efficiency. The removal efficiency is increased with longer contact times and higher biochar dosages.

- Comparison of CSBC with PAC and GAC

Our findings indicate that coconut shell biochar demonstrates notable effectiveness in removing contaminants during both the batch and column absorption treatment methods. These results suggest that coconut shell biochar could potentially outperform powdered and granular activated charcoal in terms of removal efficiency. However, further comprehensive analysis and experimentation are required to ascertain and validate these promising results.

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APPENDIX

Table 1: Efficiency of CSBC 700°C at 2hrs 7mins on removing nitrate (column method)

Bed height (cm)	Initial pH of sample	Final pH of sample	COD (mg/l)	Removal efficiency (%)
0.5	7.58	8.87	40	7.537688
1	7.82	8.28	32	15.90837
1.5	7.58	7.82	16	35.77537
2	7.82	8.62	24	61.56538
2.5	7.58	9.01	32	67.93617

Table 2: Efficiency of CSBC 445°C at 2hrs 23mins on removing nitrate (column method)

Bed height (cm)	Initial pH of sample	Final pH of sample	Removal efficiency (%)
0.5	7.96	8	19.38785
1	7.96	6.04	92.60163
1.5	7.96	5.93	95.75627
2	7.96	5.87	-
2.5	7.96	5.81	-

Table 3: Efficiency of PAC on removing nitrate (column method)

Bed height (cm)	Initial pH of sample	Final pH of sample	COD (mg/l)	Removal efficiency (%)
0.5	7.58	10.16	24	9.353786
1	7.58	10.06	40	11.78701
1.5	7.58	10.38	28	13.88522
2	7.58	9.82	16	14.95195
2.5	7.58	9.92	44	15.97461

Table 4: Efficiency of GAC on removing nitrate (column method)

Bed height (cm)	Initial pH of sample	Final pH of sample	Removal efficiency (%)
0.5	7.96	8.38	2.0937
1	7.96	8.57	3.117078
1.5	7.96	9.39	3.248521
2	7.96	9.15	4.34701
2.5	7.96	9.27	8.03680

Table 5: Efficiency of CSBC 700°C at 2hrs 7mins on removing phosphate (column method)

Bed height (cm)	Initial pH of sample	Final pH of sample	Removal efficiency (%)
0.5	8.55	8.38	3.344695
1	8.55	8.37	13.35748
1.5	8.55	8.64	20.7925
2	8.55	8.79	34.63997
2.5	8.55	8.95	9.693225

Table 6: Efficiency of CSBC 445°C at 2hrs 23mins on removing phosphate (column method)

Bed height (cm)	Initial pH of sample	Final pH of sample	Removal efficiency (%)
0.5	8.55	8.02	51.98125
1	8.55	7.95	54.96378
1.5	8.55	7.6	39.45462
2	8.55	7.05	43.33191
2.5	8.55	6.86	19.3491

Table 7: Efficiency of PAC on removing phosphate (column method)

Bed height (cm)	Initial pH of sample	Final pH of sample	Removal efficiency (%)
0.5	6.68	7.67	100
1	6.68	9.4	9.61794
1.5	6.68	9.64	12.392
2	6.68	9.96	10.8804
2.5	6.68	9.92	13.1728

Table 8: Efficiency of GAC on removing phosphate (column method)

Bed height (cm)	Initial pH of sample	Final pH of sample	Removal efficiency (%)
0.5	6.68	7.29	10.0831
1	6.68	7.03	8.20598
1.5	6.68	7.04	10.4817
2	6.68	7.04	0.59801
2.5	6.68	7.03	6.24585

Table 9: Efficiency of CSBC 700°C at 2hrs 7mins on removing nitrate (batch method)

Weight (gm)	Revolutions per minute	Initial pH of sample	Contact period	Final pH of sample	Removal efficiency (%)
4	150	8.16	30 mins	8.27	34.48197
		8.16	60 mins	8.11	34.68062
		8.16	90 mins	7.95	31.42573
		8.16	120 mins	7.89	3.109719
4	300	8.16	30 mins	7.34	28.56051
		8.16	60 mins	7.2	31.54798
		8.16	90 mins	7.99	5.432457
		8.16	120 mins	7.42	2.399144
8	150	8.16	30 mins	8.26	21.86736
		8.16	60 mins	8.24	27.93399
		8.16	90 mins	8.26	28.59108
		8.16	120 mins	7.96	33.63386
8	300	8.16	30 mins	7.27	18.03943
		8.16	60 mins	7.68	20.71363
		8.16	90 mins	7.65	22.48625
		8.16	120 mins	7.83	19.36278

Table 10: Efficiency of CSBC 445°C at 2hrs 23mins on removing nitrate (batch method)

Weight (gm)	Revolutions per minute	Initial pH of sample	Contact period	Final pH of sample	Removal efficiency (%)
4	150	7.62	30 mins	9.47	21.19476
		7.62	60 mins	9.23	33.88021
		7.62	90 mins	8.88	41.18063
		7.62	120 mins	8.63	41.56527
4	300	7.62	30 mins	8.74	32.86757
		7.62	60 mins	7.88	32.98532
		7.62	90 mins	7.89	33.09522
		7.62	120 mins	7.16	32.32593
8	150	7.88	30 mins	6.93	21.61115
		7.88	60 mins	6.75	33.52573
		7.88	90 mins	6.17	69.42612
		7.88	120 mins	6.3	44.98681
8	300	7.88	30 mins	7.26	5.672823
		7.88	60 mins	6.8	5.994393
		7.88	90 mins	7.23	12.74736
		7.88	120 mins	7.53	18.58509

Table 11: Efficiency of PAC on removing nitrate (batch method

Weight (gm)	Revolutions per minute	Initial pH of sample	Contact period	Final pH of sample	Removal efficiency (%)
4	150	7.62	30 mins	10.4	-7.00212
		7.62	60 mins	10.41	-7.76356
		7.62	90 mins	10.51	-7.55161
		7.62	120 mins	10.5	-4.95329
4	300	7.88	30 mins	9.7	1.104881
		7.88	60 mins	9.95	5.095646
		7.88	90 mins	10.46	8.970976
		7.88	120 mins	10.26	12.87104
8	150	7.88	30 mins	10.29	2.349934
		7.88	60 mins	10.38	10.8097
		7.88	90 mins	10.05	12.41755
		7.88	120 mins	10.2	13.90996
8	300	7.62	30 mins	10.55	2.527671
		7.62	60 mins	10.77	-6.60962
		7.62	90 mins	10.78	9.043096
		7.62	120 mins	10.83	16.60256

Table 12: Efficiency of GAC on removing nitrate (batch method)

Weight (gm)	Revolutions per minute	Initial pH of sample	Contact period	Final pH of sample	Removal efficiency (%)
4	150	6.86	30 mins	6.46	5.577389
		6.86	60 mins	6.76	8.378627
		6.86	90 mins	6.82	2.976838
		6.86	120 mins	6.98	4.891713
4	300	6.86	30 mins	6.91	0.242495
		6.86	60 mins	6.88	2.41659
		6.86	90 mins	6.7	6.438665
		6.86	120 mins	7.11	13.24525
8	150	6.86	30 mins	8.31	10.73668
		6.86	60 mins	7.2	15.06815
		6.86	90 mins	7.27	7.224684
		6.86	120 mins	7.03	1.597124
8	300	6.86	30 mins	7.43	15.65348
		6.86	60 mins	7.56	18.46308
		6.86	90 mins	7.63	18.49653
		6.86	120 mins	7.64	19.25746

EFFECTS OF SYNTHETIC LEACHATE ON COCONUT SHELL BIOCHAR AND COMPARATIVE STUDY ON ACTIVATED CHARCOAL

A PROJECT REPORT

submitted by

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to

the APJ Abdul Kalam Technological University

in partial fulfilment of the requirements for the award of the Degree

of

Bachelor of Technology

in

Civil Engineering

Department Of Civil Engineering

Vimal Jyothi Engineering College

Chemperi

JUNE 2023

DECLARATION

We undersigned hereby declare that the project report "Effects of Synthetic Leachate on Coconut Shell Biochar and Comparative Study on Activated Charcoal", submitted for partial fulfilment of the requirements for the award of degree of Bachelor of Technology of the APJ Abdul Kalam Technological University, Kerala is a bonafide work done by us under the supervision of Mr. Rojin P. This submission represents our ideas in our own words and where ideas or words of others have been included, we have adequately and accurately cited and referenced the original sources. We also declare that we have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in our submission. We understand that any violation of the above will be a cause for disciplinary action by the institute and the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree, diploma or similar title of any other University.

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CERTIFICATE

This is to certify that the report entitled **"Effects of Synthetic Leachate on Coconut Shell Biochar and Comparative Study on Activated Charcoal"** submitted by **Antus Sunny (VML19CE028), Anura Balakrishnan (VML19CE030), Karthik K (VML19CE059), Treesa Wilson (VML19CE099)** to the APJ Abdul Kalam Technological University in partial fulfilment of the requirements for the award of the Degree of Bachelor of Technology in Civil Engineering is a bonafide record of the project work carried out by them under our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

Project Guide	**Project Coordinator**	**Head of Department**
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ACKNOWLEDGEMENT

First and foremost, we thank god almighty who gave us strength, courage, good health and interest to begin and complete all our task successfully. We express our gratitude to respected principal, **Dr. Benny Joseph** for his permission and constant encouragement. We submit our sincere thanks respected to **Dr. Biju Mathew**, Head of Department of Civil Engineering for his support and timely suggestions. We are thankful to the project coordinator, as well as our project guide **Mr. Rojin P**, Assistant professor in Civil Engineering for his suggestions and guidance. We thank all the faculties of Civil Engineering Department for their limitless support. We profound our sincere thanks to our parents, who always pray for our progress and extend their moral and financial support for our welfare. We also thank our friends, who are with us all the time and positively supporting us in our activities.

ABSTRACT

Now a day's water scarcity is a burning issue. The world's water resources are being deteriorated due to the continuous discharge of a large number of organic and inorganic contaminants. Due to the increase in population, the demand for water also increases. Here comes the necessity of waste water treatment and removal of contaminants, thus making it a potable water. This project focuses on applications in waste water treatment using biochar to remove various pollutants such as heavy metals, chemical and organic compounds. Biochar is a lightweight black residue, made of carbon and ashes, remaining after the pyrolysis of biomass. As an emerging sorbent with great potential, biochar has shown significant advantages such as the broad sources of feed stocks, easy preparation process, and favourable surface and structural properties. Heavy metals in the water environment mostly come from anthropogenic activities such as smelting, mining, and electronic manufacturing effluents. Biochar has been suggested to be used for heavy metals removal from contaminated water. Biochar can be directly used in water and wastewater treatment as a sorbent for contaminants removal. The physical and chemical properties of biochar depend primarily on the types of feedstock and pyrolysis conditions i.e., temperature, residence time, reactor type and heating rate. Though the biochar has an excellent capability to adsorb heavy metal ions from metal contaminated solutions, this capacity is relatively lower in comparison with other known bio sorbents such as activated carbon. Hence there are several approaches to modify the biochar. The contaminated soil and water is treated with biochar and conduct batch method and column method to determine the removal efficiency of contaminants. The results of tests are to be compared and determine the efficiency of prepared biochar over other sorbents. By this comparison, it enables to utilize the biochar instead of the costly bio-sorbents.

Keywords: Biochar, waste water treatment, pyrolysis, heavy metals, sorbents

CONTENTS

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LIST OF ABBREVIATIONS

ADS	Adsorption
ASTM	American Standard Test Method
BC	Biochar
BET	Brunauer-Emmett-Teller
COD	Chemical Oxygen Demand
CSBC	Coconut Shell Biochar
CSIF	Central Sophisticated Instrumentation Facility
DES	Desorption
GAC	Granular Activated Charcoal
PAC	Powdered Activated Charcoal
RPM	Revolutions Per Minute
UV	Ultraviolet

` CHAPTER 1

INTRODUCTION

1.1 GENERAL

Water is one of the essential need of the industry as well as life on earth. Now a day's water scarcity is a burning issue. The world's water resources are being deteriorated due to the continuous discharge of a large number of organic and inorganic contaminants. Due to the increase in population, the demand for water also increases. Here comes the necessity of waste water treatment and removal of contaminants, thus making it a potable water. For the treatment of waste water various methods are available like ion-exchange, membrane separation but this need needs more financial input due to that it restrict the use of this method. Among them adsorption by using low cost adsorbent is an effective method for waste water treatment. This project focuses on applications in waste water treatment using biochar to remove various pollutants such as heavy metals and chemical compounds. Biochar is a lightweight black residue, made of carbon and ashes, remaining after the pyrolysis of biomass.

1.2 OBJECTIVES

The project focuses on the following objectives:

- Determination of properties of biochars made from coconut shell.
- Removal of contaminants like PO_4^{3-}, NO_3^- from contaminated water.
- Conduction of batch method and column method to determine the removal efficiency of contaminants from water using biochars.
- Comparison with powdered and granular activated charcoals.

1.3 SCOPE

Nowadays, water is being polluted at a higher rate. A treatment technique with low cost is required for the sustainable treatment of water. Adsorption is a low cost technology and is able to applicable to variety of pollutants. Biochar is used to improve potential carbon sink and soil carbon storage, increase nutrients in soil retention and availability of nutrients, reduction of nutrient leachate and sustain the stability of the ecosystem of the soil. A project of this type gains much importance in a state like Kerala where there are lot of reported cases of lake pollution and polluted ponds which are abandoned.

CHAPTER 2

LITERATURE SURVEY

2.1 GENERAL

The removal of pollutants from contaminated water by using biochar is reviewed in these journals. The preparation of biochar by the pyrolysis method, their properties and their role in the removal of pollutants is studied.

2.2 LITERATURE REVIEW

Masto et al., (2013): Biochar is a useful material for carbon storage in soils. In this report, they explored conversion of water hyacinth (Eichornia crassipes) to biochar as a sustainable weed management strategy, as it also has potential for improving soil quality. The optimum condition for obtaining maxi-mum stable carbon in Eichornia biochar (EBC) is 300–350 °C temperature with 30–40 min residence time. Biochar is a useful material for carbon storage in soils. In this report, the researchers explored conversion of water hyacinth to biochar as a sustainable weed management strategy, as it also has potential for improving soil quality. Soil biochemical properties and maize seedling growth were used to investigate the effects of biochar addition to the soil. The study shows that the waste Eichornia weed could be gainfully utilised as a soil quality amendment material by converting it to EBC.

Patel et al., (2017): It illustrates the procedures of batch and column experiments on water effluent. It gives an idea about the treatment methods and result analysis. Out of the various methods available removal of pollutants on a solid body, adsorption is much effective. Based on literature survey it has been found that the removal of pollutant from effluent waste stream has been carried out by various researcher in batch mode and various kinetic data has been generated. This leaves behind an unexplored area of pollutant removal by adsorption in a continuous mode, which has been selected as a focus of present study.

Zhou et al., (2018): This study aimed to evaluate the adsorption of cadmium and copper by ferromanganese binary oxide-BC composites (FMBC). The biochar were prepared and their physiochemical properties and morphologies were also examined. Kinetic modelling and adsorption isotherms were used to characterize the adsorption of Cu (II) and Cd (II) on FMBC, revealing that adsorption was well represented by pseudo-second-order kinetics and the Langmuir isotherm model. Moreover, adsorption was favoured by increased pH and high

humic acid concentration. X-ray photoelectron spectroscopy and Fourier transform infrared analyses confirmed that the heavy metal ions adsorbed on FMBC were divalent, indicating that the uptake of Cu (II) and Cd (II) was mainly due to the formation of strong mono- or multidentate inner-sphere complexes.

Xue et al., (2019): This study prepared and evaluated seven types of food waste-based biochars (FWBBs) (including meat and bone, starchy staples, leafy stemmed vegetables, nut husks, fruit pericarp, bean dreg and tea leaves). The impacts of raw materials, pyrolysis temperatures, and residence time on the removal of ammonia nitrogen at different ammonia nitrogen concentrations (5, 10, 20, 50, 100, 150 mg/L) were investigated.

Castilla-Caballero et al., (2020): Biochars are emerging eco-friendly products showing outstanding properties in areas such as carbon sequestration, soil amendment, bioremediation, bio composites, and bioenergy. These interesting materials can be synthesized from a wide variety of waste-derived sources, including lignocellulosic biomass wastes, manure and sewage sludge. In this work, abundant data on biochars produced from coconut-shell wastes obtained from the Colombian Pacific Coast are presented. Biochar synthesis was performed varying the temperature and O2 feeding in the pyrolysis reaction. Production yields and some biochar properties such as particle size, zeta potential, elemental content (C, N, Al, B, Ca, Cu, Fe, K, Li, Mg, Mn, Na, P, S, Ti and Zn), BET surface area, FT-IR spectrum, XRD spectrum, and SEM morphology are presented.

Yaashikaa et al., (2020): It focuses on an overview of remediating harmful contaminants utilizing biochar. Production of biochar utilizing various systems has been discussed. It deals with the various methods of biochar production. Production of biochars uncovers a wide variety of biomass that have been utilized as the feedstocks and pyrolyzed by various procedures to handle water pollution. The properties of resultant biochar are significantly influenced by pyrolyis temperature, feedstock, and pyrolysis technology. Biochar can be utilized as major source for removal of toxic pollutants.

Das et al., (2021): It investigates the effect of pyrolysis reactors on the properties of biochar by keeping factors such as feedstock, carbonisation temperature, heating rate and residence time constant. It focuses on the composite applications of biochar. The reactors employed were hydrothermal, fixed-bed batch vertical and fixed-bed batch horizontal-tube reactors. The vertical and tube reactors, at the same temperature, produced biochars having comparable elemental carbon content, surface functionalities, thermal degradation pattern and peak

heat release rates. The hydrothermal reactor, although, a low-temperature process, produced biochar with high fire resistance because the formed tarry volatiles sealed water inside the pores, which hindered combustion.

Liu et al., (2021): Nitrate is one of the most common water contaminants and has caused severe environmental problems. This work aimed to investigate the effects of integration of denitrifier with biochars on nitrate removal and understand the underlying mechanisms. The results showed that physiochemical properties of biochars varied according to different feedstocks, which influenced bacteria attachment and nitrate removal through adsorption. However, bacteria could colonize on biochars no matter biochars surface were favourable for bacteria attachment or not. Immobilization of denitrifier on biochars significantly improved nitrate removal efficiencies and reduced lag time.

Nakhli et al., (2021): In this work, several methods are described for preparing repacked biochar-amended soils. It deals with the pre-column packing, determination of optimum moisture content and bulk density of biochar-amended soils. The modifications are rinsing and oven-drying biochar, determining the optimum moisture content to achieve a homogenous mixture, determining the desired bulk density before column packing, and mixing and packing under wet conditions.

Antunes et al., (2022): In this study, researchers investigate on the phosphorous removal, by using algae biochar. A potential circular economy approach for microalgae was investigated considering the crucial stages of bio refinery. Important stages, such as drying of biomass, production of biochar (pyrolysis), and application of biochar for phosphorus removal were studied and reported. The physicochemical properties of biomass as well as biochar were characterized and were correlated with their capacity to adsorb phosphorus (P).

Wang et al., (2022): This work investigates on the impact of the biochar microstructure on the hydraulic conductivity of sand-biochar mixtures. It experimentally investigated the hydraulic properties of sand-biochar mixtures for uniformly graded sand. This approach enables to statically evaluate the interparticle porosity and tortuosity of biochar. The researchers showed that by excluding biochar's intraparticle porosity, the hydraulic conductivity prediction accuracy can be significantly improved, thus providing a more accurate prediction of the hydraulic behaviour of the soil-biochar filters.

2.3 LITERATURE GAP

Although several studies have investigated the removal efficiency of biochar in various applications, there is a significant literature gap regarding its effectiveness in the removal of heavy metals and chemical compounds from contaminated water sources. While some research has touched upon this topic, existing studies predominantly focus on organic pollutants or agricultural applications of biochar. Limited attention has been given to assessing the potential of biochar as an efficient and sustainable adsorbent for heavy metal removal, particularly in industrial wastewater treatment scenarios. Therefore, this project aims to fill this literature gap by investigating the removal efficiency of coconut shell biochar in the context of nitrate and phosphate contaminated water.

CHAPTER 3

METHODOLOGY

3.1 GENERAL

The methodology for biochar treatment in wastewater can be summarized into several key steps. They are biochar preparation, preparation of synthetic water sample, conduction of iodine value test, conduction of batch and column methods of treatment, evaluation and analysis of results at various parameters.

3.2 BIOCHAR PREPARATION

Coconut shell biochar is a type of biochar derived from coconut shells, which are a waste product of the coconut industry. The preparation of coconut shell biochar involves several steps. They are collection and preparation of coconut shells, carbonization, heating and pyrolysis, cooling and quenching, crushing and sizing and storage.

3.3 PREPARATION OF SYNTHETIC WATER SAMPLE

Synthetic water samples containing nitrates and phosphates are laboratory-prepared solutions used for experimental purposes to simulate the presence of these contaminants in water. In the laboratory, synthetic water samples containing nitrates and phosphates are used for various purposes, including studying the behaviour and treatment of these contaminants, assessing the effectiveness of treatment technologies, conducting adsorption experiments.

3.4 CONDUCTION OF IODINE VALUE TEST

The iodine value test is a common method used to determine the efficiency of biochar in adsorbing organic compounds. Specifically, it measures the amount of iodine in milligrams that can be adsorbed by a certain weight of biochar material. The iodine value test provides an indication of the surface area and porosity of the biochar, as well as its potential for adsorbing organic pollutants. It is important to note that the test results should be interpreted in conjunction with other characterization and performance tests to fully assess the effectiveness of the biochar for specific applications.

3.5 CONDUCTION OF BATCH EXPERIMENT

Batch tests were performed to find out the maximum capacity of adsorbent. For conducting batch experiment 200ml of sample is to be taken in a beaker in which 4 gm and 8gm of biochar is to be added in to the beaker and putting on to the magnetic stirrer and stirring is started at 150 and 300 revolutions per minutes respectively. 50 ml of sample is to be drawn in time interval of 30, 60, 90 and 120 minutes from this beaker. Then filtered on Whatman filter paper and the filtrate is analyzed in spectrophotometer for respective concentration. At the end of 2hr the stirring is stopped and the experiment is terminated.

3.6 CONDUCTION OF COLUMN EXPERIMENT

Column tests were then to be performed to provide a real-life treatment process but on a smaller scale. Continuous experiment were carried out in glass column having 7.5 cm length and 5 cm diameter, in which adsorbent was filled in the column and at the top and bottom filter beds are placed for the supporting purpose. Effluent sample was feed from top and the sample was collected from the bottom. The experiment were carried out by changing the bed height of adsorbent as 0.5 cm, 1 cm, 1.5 cm, 2 cm and 2.5 cm for coconut shell biochar, powdered activated charcoal and granular activated charcoal.

3.7 EVALUATION AND ANALYSIS OF RESULT

The analysis of the respective concentration of filtrate effluent sample is done by using UV-Visible Double Beam Spectrophotometer.

CHAPTER 4

BIOCHAR

4.1 GENERAL

Biochar is the lightweight black residue, made of carbon and ashes, remaining after the pyrolysis of biomass. Biochar is defined by the International Biochar Initiative as "the solid material obtained from the thermochemical conversion of biomass in an oxygen-limited environment". Biochar is a stable solid that is rich in pyrogenic carbon. Biochar can be produced from almost as many types of feedstock as there are types of biomass including: agricultural wastes, rice husks, bagasse, paper products, animal manures, and even urban green waste.

4.2 COCONUT SHELL BIOCHAR

Coconut shell biochar refers to a type of charcoal-like substance that is produced from coconut shells through a process called pyrolysis. Pyrolysis involves heating the coconut shells in the absence of oxygen, which leads to the decomposition of organic material and the production of biochar. Coconut shell biochar is known for its high carbon content, porous structure, and stable composition. In environmental remediation, coconut shell biochar is utilized for its adsorption properties. It can effectively remove pollutants, heavy metals, and organic contaminants from water and soil. Its porous structure provides a large surface area for adsorption, making it an environmentally friendly and cost-effective solution for water and soil treatment. The CSBC is shown in fig.4.1.

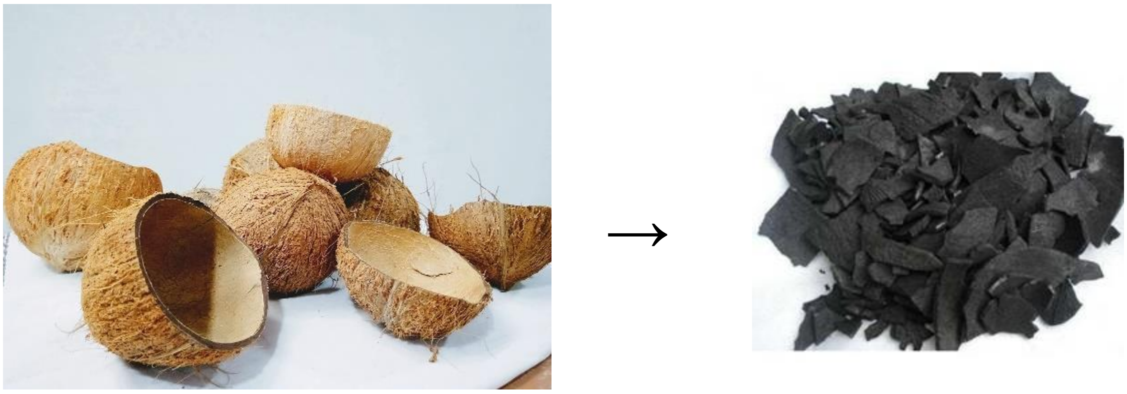


Fig. 4.1 Coconut shell biochar (Caballero et al. 2020)

CHAPTER 5

BET ANALYSIS

5.1 GENERAL

Brunauer-Emmett-Teller (BET) surface area analysis is the multi-point measurement of an analyte's specific surface area (m2/g) through gas adsorption analysis, where an inert gas such as nitrogen is continuously flowed over a solid sample, or the solid sample is suspended in a defined gaseous volume.

5.2 BET MEASUREMENT

BET analysis requires measurement of an adsorption isotherm. Because the BET model uses the relative pressure of the adsorptive, it is necessary that the gas be condensable at the adsorption temperature or the gas is really a vapour.
The measurement involves:

- Putting a known amount of sample into a sample cell or container.
- Outgassing or other treatment of the sample, to remove impurities and moisture.
- Increasing the pressure of the gas, while measuring the amount adsorbed on the surface of the sample. For the best precision, this is done at a number of discrete pressures, and with a wait for equilibrium and measurement of the amount adsorbed at each point.
- The saturation vapour pressure is measured at the same time, or it may be calculated from knowledge of the temperature.
- BET is most widely performed using adsorption of Nitrogen gas at 77 K, the boiling point of liquid nitrogen, but other species and temperatures are also used such as Argon at 87 K (liquid Argon temperature), Krypton at 77 K, Carbon dioxide at 0 °C or at 25 °C, etc.

5.3 BET ANALYSIS RESULTS

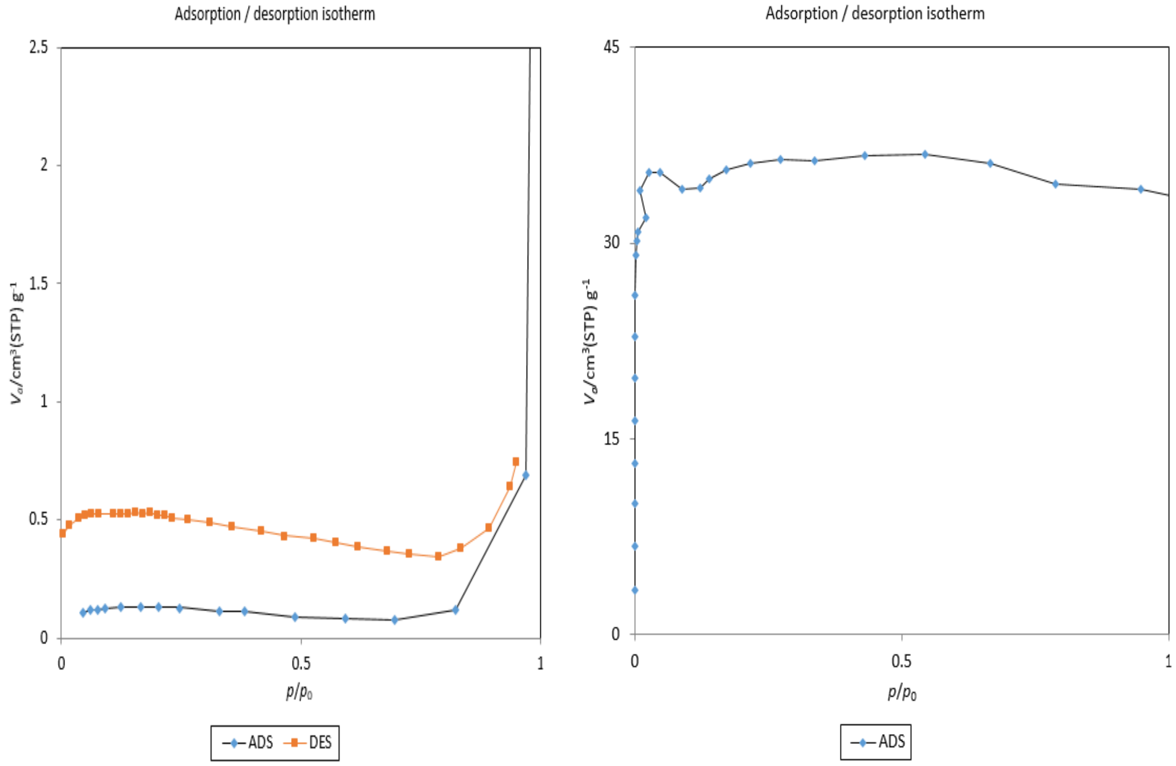
5.3.1 General

The BET (Brunauer-Emmett-Teller) Surface Area Analysis were conducted for coconut shell biochars pyrolyzed at 700^0C and 445^0C from Central Sophisticated Instrumentation Facility (CSIF), University of Calicut. The analysis was performed using adsorption of Nitrogen gas at adsorption temperature of 77 K.

5.3.2 Adsorption/desorption isotherm

A plot of relative pressure verses volume adsorbed obtained by measuring the amount of an inert gaseous or liquid substance (sorbent, usually H2 or N2) which adsorbs onto the surface of interest (sorbate), and the subsequent amount that desorbs at a constant temperature. That is, relative pressure 'p/p_0'(where, 'p' is the partial vapour pressure of adsorbate gas in equilibrium with the surface and 'p_0' is the saturated pressure of adsorbate gas) in X-axis and volume adsorbed 'V_a' in Y-axis.

The obtained adsorption/desorption isotherm for coconut shell biochars pyrolyzed at 445^{0}C and 700^{0}C are shown in fig.5.1.

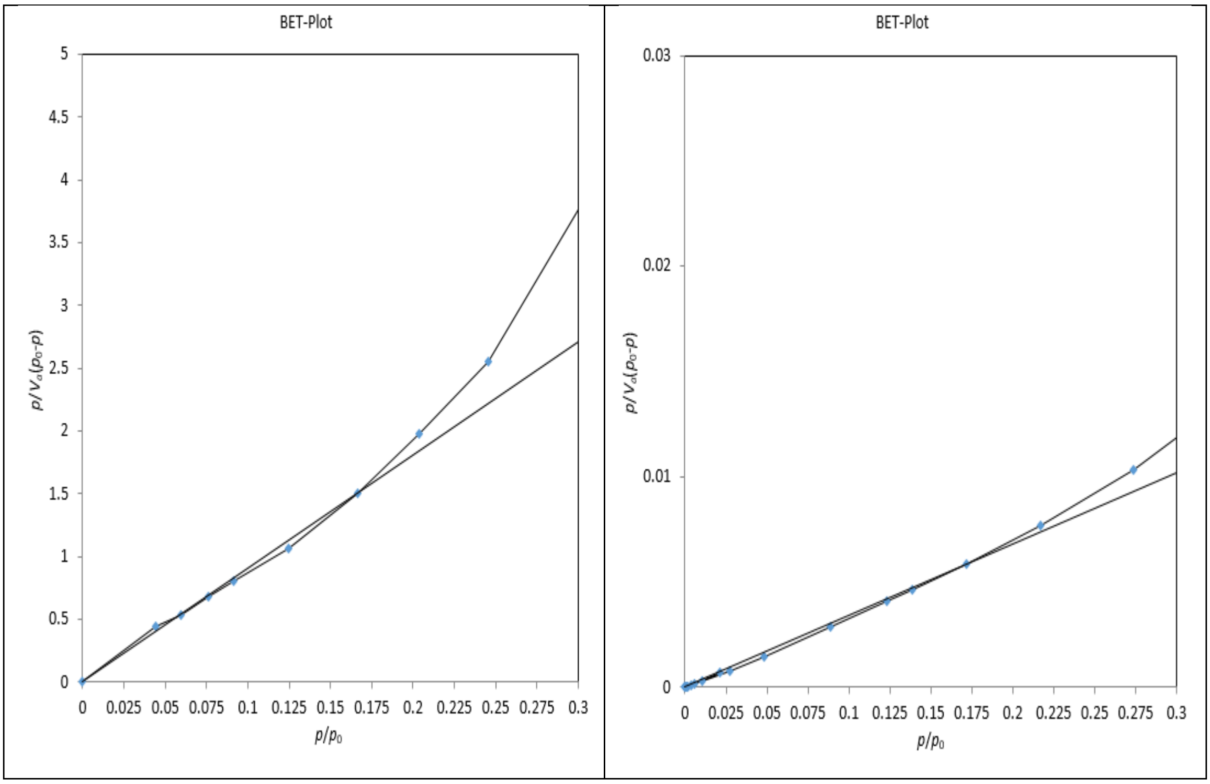


(a) (b)

Fig.5.1 Adsorption/desorption isotherm of CSBC 445^{0}C (a) and CSBC 700^{0}C (b)

5.3.3 BET Plot

A plot of $(p/V_a(p_0 - p))$ against (p/p_0), is called the BET plot, where 'p' is the partial vapour pressure of adsorbate gas in equilibrium with the surface, 'p_0' is the saturated pressure of adsorbate gas and 'Va' is the volume adsorbed. The obtained BET plot for coconut shell biochars pyrolyzed at 445^{0}C and 700^{0}C are shown in fig.5.2.



(a) (b)

Fig.5.2 BET plot of CSBC 445^{0}C (a) and CSBC 700^{0}C (b)

The obtained results of the biochars after the BET plot are given in table 5.1.

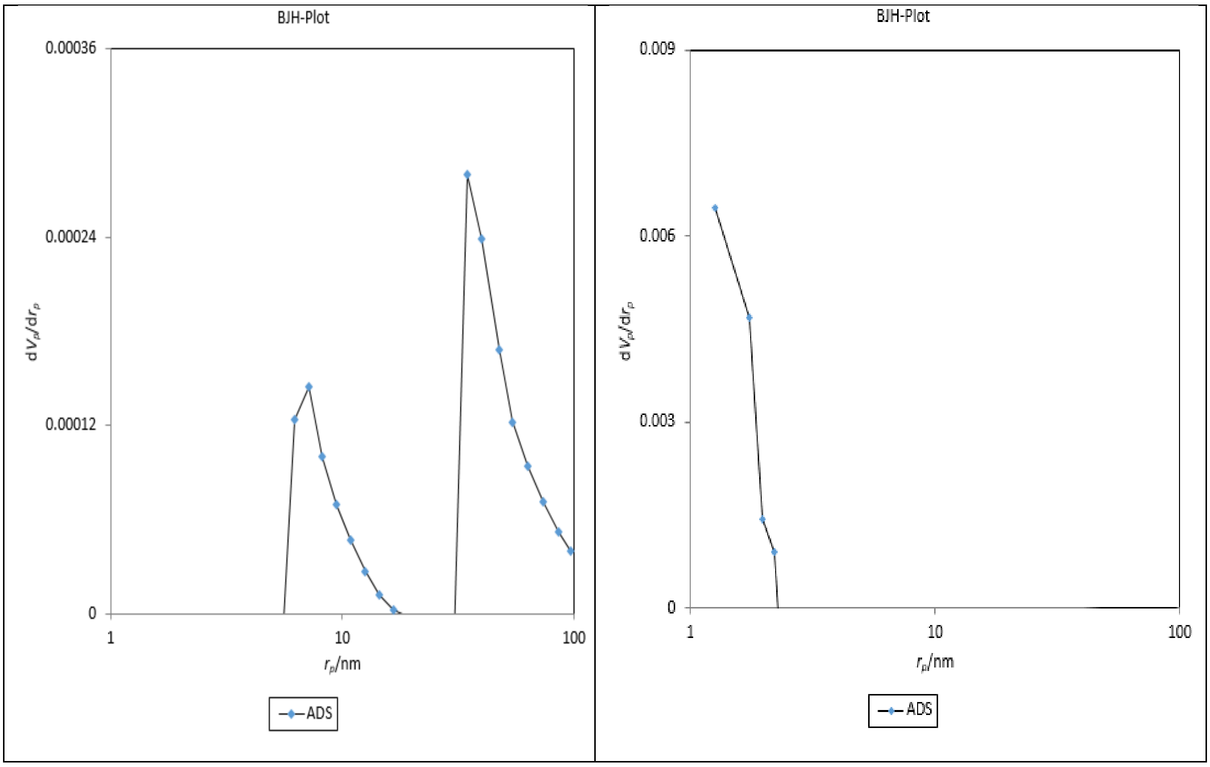
Table 5.1. BET plot results

Parameters	Coconut Shell Biochar-445^{0}C	Coconut Shell Biochar-700^{0}C
Surface area, m^2/g	0.48234	128.3
Vm, monomolecular adsorption volume, cm^3/g	0.1108	29.477
Total pore volume, cm^3/g	0.0079141	0.052196
Mean pore diameter, nm	65.631	1.6273

From the result we can understand that the 700^{0}C pyrolyzed CSBC has more surface area than 445^{0}C CSBC.

5.3.4 BJH Plot

BJH is a method to determine pore size distribution. The graph is obtained by percentage change of pore volume ($\Delta V_p / \Delta r_p$) against micropore radius (r_p). The obtained BJH plot for coconut shell biochars pyrolyzed at 445^{0}C and 700^{0}C are shown in fig.5.3. The results obtained from the BJH method are given in table 5.2.



(a) (b)

Fig.5.3 BJH plot of CSBC 445^{0}C (a) and CSBC 700^{0}C (b)

Table 5.2 BJH method results

Parameters	Coconut Shell Biochar-445^{0}C	Coconut Shell Biochar-700^{0}C
Pore volume, V_p, cm^3/g	0.0076571	-0.00052113
Pore radius, r_p, nm	34.75	1.26
Surface area of pore, a_p, m^2/g	-0.08798	5.8781

CHAPTER 6

PREPARATION OF BIOCHAR

6.1 GENERAL

The common thermochemical techniques used for biochar production include pyrolysis, hydrothermal carbonization, gasification, flash carbonization and torrefaction. Of all these methods, pyrolysis is the most commonly used to produce biochar.

6.2 SLOW PYROLISIS

Slow pyrolysis is the method used when char is the primary product. The general method is running the process between 400 to 800 °C and has a heating rate under 10 °C per minute. The feedstock used in the process is of larger particle size, several methods can use large pieces of wood if the feeding system can handle it. To optimize the production of char vapour is kept in the process for a longer duration of time. These technologies have been known and used for a long time. New industrial processes for slow pyrolysis is producing both char and can collect the other products or use them for heat and power production. The bio-oil can also contain valuable chemicals such as acetone, methanol and acetic acids. A slow pyrolysis process can have several stages for separation of the products created in the process. In general, a slow pyrolysis process produces char and gas, some parts of the product gas can be condensed into liquid fractions. The amount is these product is affected by the type of feedstock and process set up. Depending on market demand for the various products the process should be developed to maximize profit for the situation.

6.3 PROCEDURE FOR PREPARATION OF BIOCHAR

The physical and chemical properties of biochar depend primarily on the types of feedstock and pyrolysis conditions i.e., temperature, residence time, reactor type and heating rate. The biochar has a great potential for sorption from aqueous solutions

6.3.1 Selection of Feedstock:

Any organic material can be used as a feedstock for making biochar, such as wood chips, coconut shells, or water hyacinth. Choose a feedstock that is readily available in our area and that will produce a high-quality biochar.

6.3.2 Drying:

Once the feedstock is selected, it needs to be dried to remove the moisture content. This is done by spreading the material out in the sun or by using a drying machine.

6.3.3 Preparation of Feedstock:

If the feedstock is in large pieces, it may need to be chipped or shredded into smaller pieces that are suitable for pyrolysis.

6.3.4 Load the Pyrolysis Chamber:

The pyrolysis chamber can be any container that can withstand high temperatures, such as a carbonizer. The schematic diagram of carbonizer is shown in fig.6.1. Fill the carbonizer with the prepared feedstock, leaving enough space for air to circulate around the material.

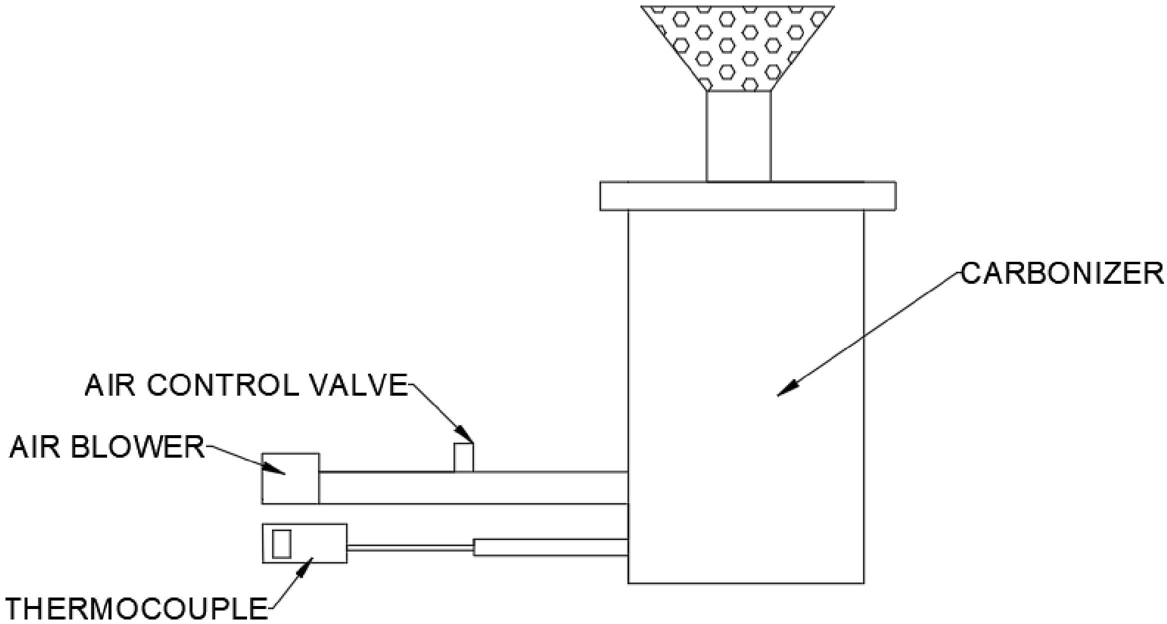


Fig.6.1 Schematic diagram of carbonizer

6.3.5 Heat the Chamber:

Start a fire at the bottom of the chamber to heat the feedstock. The fire should be hot enough to pyrolyze the feedstock, but not so hot that it burns it completely to ash. Cover the chamber

to limit the amount of oxygen that enters and allow the pyrolysis process to take place. Fig. 6.2 shows the various stages of preparation of biochar.

Fig 6.2 Preparation of biochar

6.3.6 Monitor the Process:

The pyrolysis process can take several hours to complete, depending on the size of the feedstock and the temperature of the fire. Monitor the process to ensure that the biochar is not overcooked or undercooked. When the process is complete, the biochar should be dark in colour and have a light, porous texture.

6.3.7 Cool and Store the Biochar:

Once the pyrolysis process is complete, allow the biochar to cool before removing it from the chamber. Store the biochar in a dry place to prevent it from absorbing moisture and losing its effectiveness.

6.4 BIOCHARS PREPARED

For a maximum yield of biochar, the technique chosen for production must be appropriate depending on the biomass type and also the process conditions such as heating rate, temperature, residence time, etc. must be optimum. These conditions are crucial since they may affect the physical and chemical states of biochar during the production process. The biochars prepared on various temperature and residence time are shown in the table 6.1.

Table 6.1: Biochars prepared

BIOCHAR TYPE	TEMPERATURE (ºC)	DURATION	DATE
COCONUT SHELL BIOCHAR	502.8	1 hr 22 min	15/11/2022
	809.3	2 hrs 16 min	23/11/2022
	700	1hr 40 min	22/12/2022
	445	2 hrs 23 min	22/12/2022
	716	2 hrs 22 min	25/12/2022
	700	2 hrs 7 min	26/12/2022
	700	1 hr 39 min	26/12/2022
	700	1 hr 27 min	27/12/2022
	702	1 hr 24 min	28/12/2022
	700	1 hr 38 min	28/12/2022
	700	2 hrs 10 min	28/12/2022
	800	1 hr 35 min	29/12/2022

CHAPTER 7

IODINE VALUE TEST FOR BIOCHAR

7.1 GENERAL

American standard test method (ASTM D4607-94, 2006) was used to determination of iodine number of activated carbon. The amount of iodine absorbed [mg/g (carbon)] at residual iodine concentration of 0.02N is reported as iodine number. The Iodine number test is commonly used method to measure the surface area of biochar. This test is based on the principle that iodine is absorbed by the surface of the biochar, and the amount of iodine absorbed is proportional to the surface area of the biochar. The iodine number is a relative indicator of porosity in an activated carbon. It does not necessarily provide a measure of the carbon's ability to absorb other species. This test method is based upon a three-point adsorption isotherm.

7.2 MATERIALS REQUIRED

These are the various materials required for the iodine value test:

- Analytical balance
- Biochar sample
- Erlenmeyer flask
- Desiccator
- Burette
- Conical flask
- Pipette
- Whatman filter paper
- Funnel

7.3 REAGENTS

The various reagents used for the iodine value test are listed below:

- Hydrochloric acid (HCl): Dilute 70ml conc. HCl to 550ml distilled water.
- Sodium thiosulphate ($Na_2S_2O_3$) solution (0.1N): Add 24.82g $Na_2S_2O_3$ to 75ml distilled water. Add 0.1g Na_2CO_3 to it and dilute to 1L.

- Standard Iodine solution (0.1N): Weigh 12.7g iodine and 19.1g KI, mix it with 2 to 5ml distilled water and dilute it to 1L.
- Potassium Iodate solution (0.1N): Add 100 ml distilled water to 3.5667g KIO_3 and dilute it to 1L.
- Starch solution

7.4 PROCEDURE

- Weighted the three biochar dosages of individual temperature (W_1, W_2, W_3 grams) using electronic balance.
- Each weighted sample of carbon was transferred to a clean, dry 250cm³ Erlenmeyer flask equipped with a ground glass stopper.
- 10ml of HCl solution is added to each flask containing carbon. Each flask is stopped and swirled gently until the carbon is completely wetted.
- The stoppers are loosened to vent the flasks and they are heated to bring the contents to boil for 30 sec. The flasks are removed and cooled in room temperature (29ºC).

Fig. 7.1 Titration

- 100ml of 0.1N iodine solutions are pipetted in to each flask. The addition of iodine solution to the three flasks are staggered to minimize delay in handling.
- The flask is immediately stoppard and shaken vigorously for 30seconds. Each mixture is quickly filtered by gravity through one sheet of folded Whatman filter paper.
- Clean beakers are used to collect the filtrates. Each filtrate is swirled and 50ml of it is pipetted in to clean 250cm³ Erlenmeyer flask.

- Each filtrate is titrated with 0.1N sodium thiosulphate solutions until the solution turned yellow as shown in fig.7.1.
- 2ml of freshly prepared starch indicator solution is added and the titration continued with sodium thiosulphate until one drop produced a colourless solution.
- The volume of sodium thiosulphate used is noted.

7.5 EQUATION

Two calculations are required for each carbon dosage, as X/M and C.

Iodine absorbed (X/M) per gram of carbon (mg/g) is calculated as follows:

$$\frac{X}{M} = \frac{[A-(DF)(B)(S)]}{M} \qquad \rightarrow \quad (1)$$

Where,

A= (N_2) iodine (12693.0)

N_2=Iodine (N) = 0.1

S=Sodium thiosulphate (cm^3)

M=Carbon used (g)

DF=Dilution factor= (100+10)/50=2.2

B= (N1) (126.93)

N_1=Sodium thiosulphate (N) = 0.1

The residual filtrate (C) is calculated as follows:

$$C = \frac{N1 * S}{F} \qquad \rightarrow \quad (2)$$

Where,

N_1 = Sodium thiosulphate (N) = 0.1

F = Filtrate, mL

S = Sodium thiosulphate, mL

Carbon dosage can be estimated as follows:

$$M = \frac{[A-(DF)(C)(126.93)(50)]}{E} \qquad \rightarrow \quad (3)$$

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Where,

M= Carbon, gm

A= (N_2)(12693.0)

DF= Dilution factor

C= Residual iodine

E= Estimated iodine number of carbon

Three carbon dosages are calculated using three values of C (usually 0.01, 0.02 and 0.03).

7.6 IODINE VALUE TEST 1

The below tables show the observations, calculations, result and inference of the iodine value test conducted for coconut shell biochar.

7.6.1 Observations

The observed values of iodine value test titrations carried out in Set 1 (75µ passing) and Set 2 (75µ retained) are tabulated in table 7.1.

Table 7.1: Observation of titrations

Set No.	Trial No.	Weight of biochar (g)	Volume of biochar (ml)	Burette reading of $Na_2S_2O_3.5H_2O$ (ml)			Volume of $Na_2S_2O_3.5H_2O$ consumed (ml)
				Initial reading (ml)	Intermediate reading (ml)	Final reading (ml)	
1	1	1.450	50	0	36.8	39.7	39.7
	2	1.980	50	0	27.4	28.7	28.7
	3	2.259	50	0	30.8	32.3	32.3
2	4	1.700	50	0	40.2	41.7	41.7
	5	1.980	50	0	40.8	43.1	43.1
	6	2.259	50	0	40.2	41.6	41.6

7.6.2 Calculations

The tables 7.2 and 7.3 shows the calculations for X/M and C values, using equations (1), (2) and (3).

Table 7.2: Calculations for the y axis of the graph

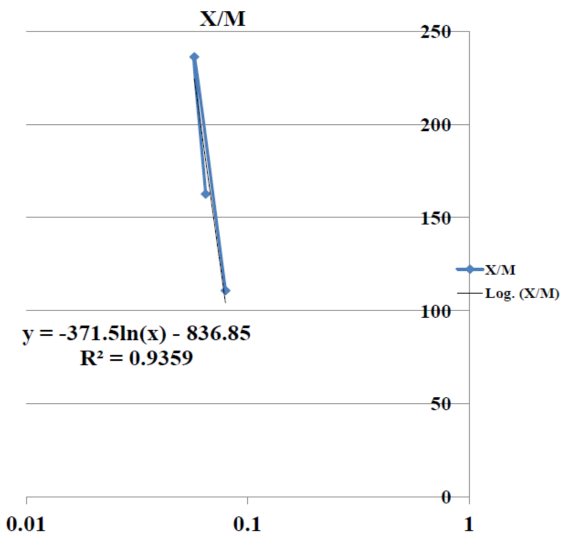
X/M								
	N1	N2	A	DF	B	S	M	X/M
	0.1	0.1	1269.3	2.2	12.693	39.7	1.45	110.82300
1	0.1	0.1	1269.3	2.2	12.693	28.7	1.98	236.29490
	0.1	0.1	1269.3	2.2	12.693	32.3	2.259	162.60970
	0.1	0.1	1269.3	2.2	12.693	41.7	1.7	61.67305
2	0.1	0.1	1269.3	2.2	12.693	43.1	1.98	33.20694
	0.1	0.1	1269.3	2.2	12.693	41.6	2.259	47.64792

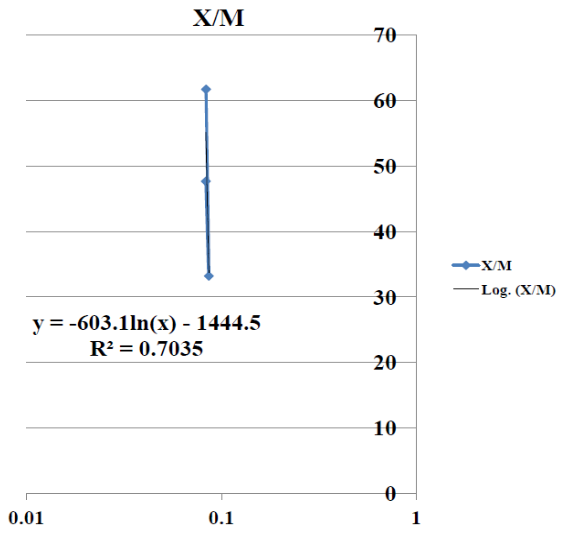
Table 7.3: Calculations for the x axis of graph

Set No.	C			
	N1	S	F	C
	0.1	39.7	50	0.0794
1	0.1	28.7	50	0.0574
	0.1	32.3	50	0.0646
	0.1	41.7	50	0.0834
2	0.1	43.1	50	0.0862
	0.1	41.6	50	0.0832

7.6.3 Graphical Representation

The graph shown in fig.7.2 is the graphical representation for iodine value test. It is obtained by plotting X/M (as shown in table 7.2) on X-axis and C (as shown in table 7.3) on Y-axis.





Set 1 Set 2

Fig.7.2 Graphical representation for the iodine test 1

7.6.4 Results from Graph

Iodine Value of Biochar;

- Set 1

  $R^2=0.9359$

  y=-371.5 ln(x)-836.85=-371.5 ln(0.02)-836.85=616.46

- Set 2

  $R^2=0.7035$

  y=-603.1ln(x)-1444.5=-603.1 ln(0.02)-1444.5=914.841

  Where, R^2 is the regression coefficient

7.6.5 Inference

Based on the obtained iodine value of the coconut shell biochar, it can be inferred that the biochar possesses a relatively high degree of unsaturation. This suggests that the biochar may have significant potential as an absorbent material for capturing and removing pollutants.

7.7 IODINE VALUE TEST 2

The below tables show the observations, calculations, result and inference of the iodine value test conducted for coconut shell biochar.

7.7.1 Observations

The observed values of iodine value test titrations carried out in Set 1, 2 and 3 (425µ passing) are tabulated in table 7.4.

Table 7.4: Observation of titrations

Set No.	Trial No.	Weight of biochar (g)	Volume of biochar (ml)	Burette reading of $Na_2S_2O_3.5H_2O$ (ml)			Volume of $Na_2S_2O_3.5H_2O$ consumed (ml)
				Initial reading (ml)	Intermediate reading (ml)	Final reading (ml)	
1	1	5.6690	50	0	30.7	31.6	31.6
	2	6.6003	50	0	21.6	22.8	22.8
	3	7.5310	50	0	30.8	31.8	31.8
2	4	4.2520	50	0	33.9	34.6	34.6
	5	4.9500	50	0	30.4	31.4	31.4
	6	5.6480	50	0	28	29	29
3	7	2.8340	50	0	29.1	30	30
	8	3.3001	50	0	29.5	30.6	30.6
	9	3.7650	50	0	30.4	30.8	30.8

7.7.2 Calculations

The tables 7.5 and 7.6 shows the calculations for X/M and C values, using equations (1), (2) and (3).

Table 7.5: Calculations for the y axis of graph

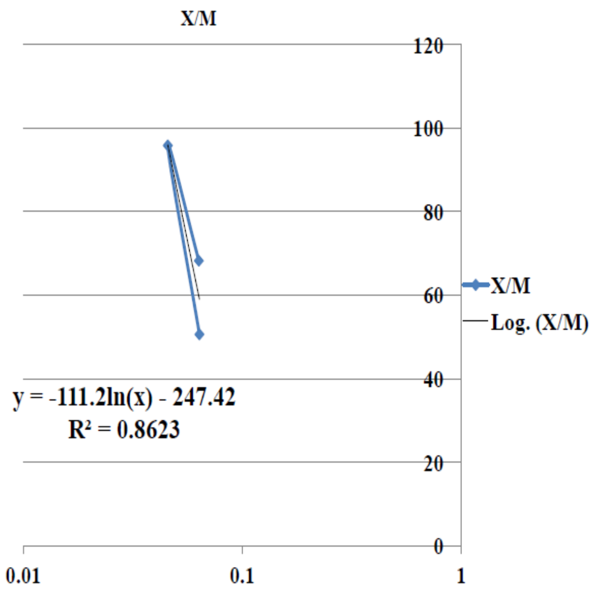
X/M								
	N1	N2	A	DF	B	S	M	X/M
1	0.1	0.1	1269.3	2.2	12.693	31.6	5.6690	68.24531
	0.1	0.1	1269.3	2.2	12.693	22.8	6.6003	95.84703
	0.1	0.1	1269.3	2.2	12.693	31.8	7.5310	50.63042
2	0.1	0.1	1269.3	2.2	12.693	34.6	4.2520	71.28618
	0.1	0.1	1269.3	2.2	12.693	31.4	4.9500	79.28638
	0.1	0.1	1269.3	2.2	12.693	29	5.6480	81.35386
	0.1	0.1	1269.3	2.2	12.693	30	2.8340	152.2802
	0.1	0.1	1269.3	2.2	12.693	30.6	3.3001	125.6954
	0.1	0.1	1269.3	2.2	12.693	30.8	3.7650	108.6912

Table 7.6: Calculations for the x axis of graph

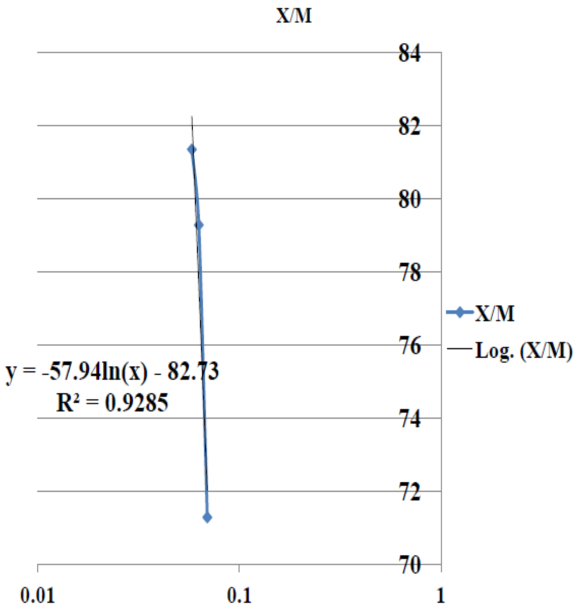
C				
	N1	S	F	C
1	0.1	31.6	50	0.0632
	0.1	22.8	50	0.0456
	0.1	31.8	50	0.0636
2	0.1	34.6	50	0.0692
	0.1	31.4	50	0.0628
	0.1	29	50	0.0580
3	0.1	30	50	0.0600
	0.1	30.6	50	0.0612
	0.1	30.8	50	0.0616

7.7.3 Graphical Representation

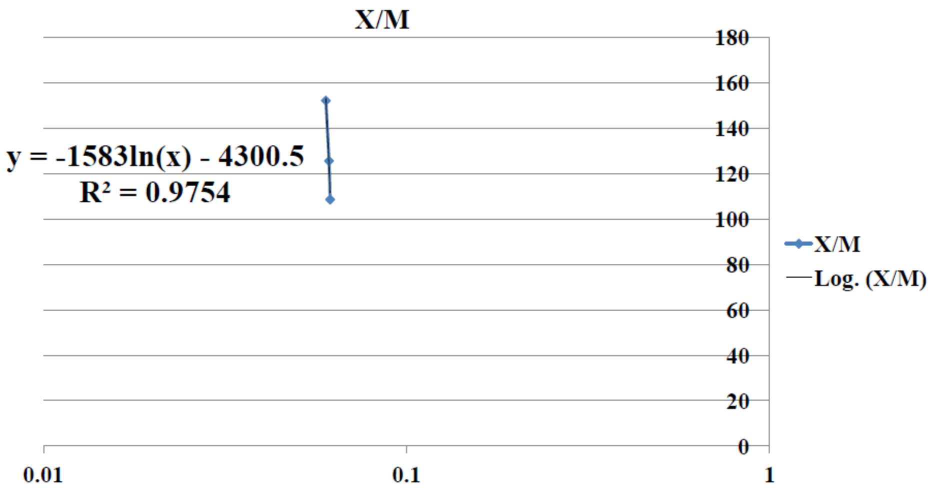
The graph shown in fig.7.3 is the graphical representation for iodine value test. It is obtained by plotting X/M (as shown in table 7.5) on X-axis and C (as shown in table 7.6) on Y-axis.



Set 1



Set 2



Set 3

Fig.7.3 Graphical representation for the iodine test 2

7.7.4 Results from Graph

Iodine Value of Biochar

- SET 1

  R^2=0.8623

  y=-111.2ln(x)-247.42=-111.2 ln(0.02)-247.42=187.5969

- SET 2

  R^2=0.9285

  y=-57.94ln(x)-82.73=-57.94 ln(0.02)-82.73=143.9326

- SET 3

  R^2=0.9754

  y=-1583ln(x)-4300.5=-1583 ln(0.02)-4300.5=1892.232

7.7.5 Inference

The iodine value exhibited by the CSBC indicates a lower degree of carbonaceous surface adsorption sites. Hence, this BC shows a reduced capacity for adsorbing contaminants. Therefore the CSBC may have limited effectiveness in applications requiring high adsorption or filtration capabilities.

CHAPTER 8

PREPARATION OF SYNTHETIC SAMPLE

8.1 GENERAL

Effluent samples can vary significantly in composition and quality depending on the source and time of sampling. By preparing synthetic water samples, specific contaminants and their concentrations can be precisely controlled, allowing for consistent and repeatable testing and treatment evaluations. This control is essential for research, development, and optimization of treatment processes.

8.2 PREPARATION OF SYNTHETIC PHOSPHATE WATER

8.2.1 General

Synthetic phosphate water is a solution containing inorganic phosphate salts and is commonly used in biological and chemical research. Here's how you can prepare synthetic phosphate water:

8.2.2 Materials

Sodium phosphate monobasic (NaH_2PO_4)
Sodium phosphate dibasic (Na_2HPO_4)
Distilled or deionized water
Graduated cylinder or volumetric flask
Stirring rod

8.2.3 Procedure

- Calculate the desired concentration of phosphate in the solution. For example, if you want to prepare a 0.1 M solution of phosphate, you will need to dissolve 1g of Na_2HPO_4 and 1g of NaH_2PO_4 in 1 litre of water.
- Weigh out the required amount of NaH_2PO_4 and Na_2HPO_4 using a balance and transfer them into a clean, dry glass beaker.
- Add a small amount of water (about 100 mL) to the beaker and stir the mixture with a stirring rod until the salts are completely dissolved.

- Transfer the solution to a graduated cylinder or volumetric flask, and add enough water to make up the final volume. For example, if you want to prepare 1 litre of solution, add water to the 1 litre mark.
- Stir the solution thoroughly to ensure that the salts are evenly distributed.

8.3 PREPARATION OF SYNTHETIC NITRATE WATER

8.3.1 General

It is not recommended to intentionally prepare synthetic nitrate-containing water as nitrates can have harmful effects on human health in high concentrations. However, if you need to prepare a nitrate-containing solution for laboratory purposes, here are the steps:

8.3.2 Materials

Distilled water
Potassium nitrate (KNO_3)
Measuring cylinder or beaker
Stirring rod

8.3.3 Procedure

- Measure the required volume of distilled water using a measuring cylinder or beaker.
- Weigh the appropriate amount of potassium nitrate (KNO_3) needed to achieve the desired concentration.
- Add the KNO_3 to the distilled water and stir using a stirring rod until it dissolves completely.
- Measure the concentration of the nitrate-containing water.

CHAPTER 9

BATCH AND COLUMN EXPERIMENTS

9.1 BATCH EXPERIMENT

9.1.1 General

Batch experiments, also known as static systems, are carried out by adding certain amount of solid into solution containing specific concentration of contaminants with a specific solid/liquid (S/L) ratio. These mixtures are vigorously stirred or shaken during the entire reaction time. The concentration of contaminant in solution is monitored and its change is thus regarded as the amount of contaminant to be partitioned onto solid. The merit of the batch approach lies in that it does not require much space of experiment apparatus while all variables of interest could be obtained experimentally. A batch adsorption method using biochar is a common approach for wastewater treatment. In this method, biochar is added to a batch of wastewater and allowed to interact with the contaminants present in the water. The biochar acts as an adsorbent, binding the contaminants onto its surface through various physical and chemical interactions. The effectiveness of a batch adsorption method using biochar can be influenced by several factors, including biochar properties, wastewater characteristics, contact time, agitation, and other operational parameters.

9.1.2 Apparatus Required

The following are the various apparatus required for the batch experiment.

- Magnetic stirrer
- Magnetic Beads
- Beakers
- Weighing machine
- Filter papers
- Funnel
- Conical flask
- China dish

9.1.3 Procedure

- Take synthetic water sample in a beaker.
- Add suitable different proportions (4gm, 8gm) of biochar to the beaker.
- Keep the beaker with the magnetic beads on a magnetic stirrer and fix 150 and 300 revolutions per minute for each proportions.
- Take small amount of sample at 30, 60, 90 and 120 minutes.
- Filter the sample on a filter paper and analyse the results.
- Stop the stirrer after 2 hours. The conduction of the experiment is shown in figure 9.1.

Fig.9.1 Conduction of batch experiments at 150 and 300 rpm

9.1.4 Result

i) Nitrate Batch Test

The obtained results of the batch experiment to check the nitrate removal efficiency of coconut shell biochars, powdered activated charcoal and granular activated charcoal are shown here.

1. Coconut Shell Biochar, 700°C at 2hrs 7mins

The graphical representation of the removal efficiency of the biochar at various proportions and at different revolutions per minute are shown in fig.9.2.

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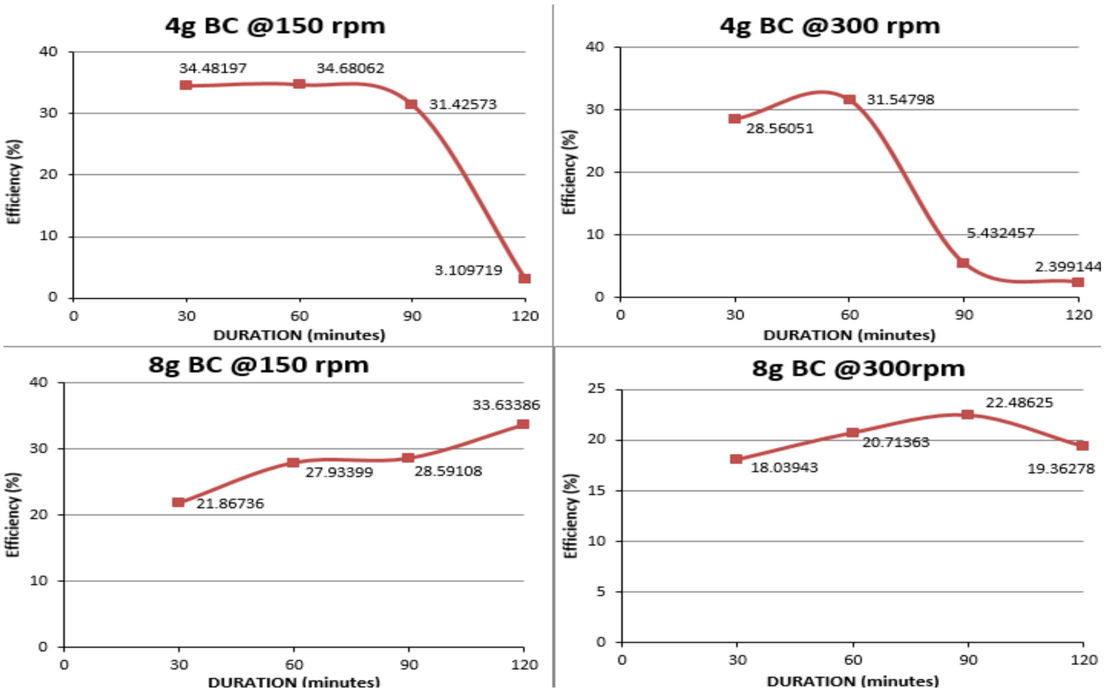

Fig.9.2 Duration v/s efficiency graphs of 700^{0}C CSBC on nitrate removal

2. Coconut Shell Biochar, 445°C at 2hrs 23mins

The graphical representation of the removal efficiency of the biochar at various proportions and at different revolutions per minute are shown in fig.9.3.

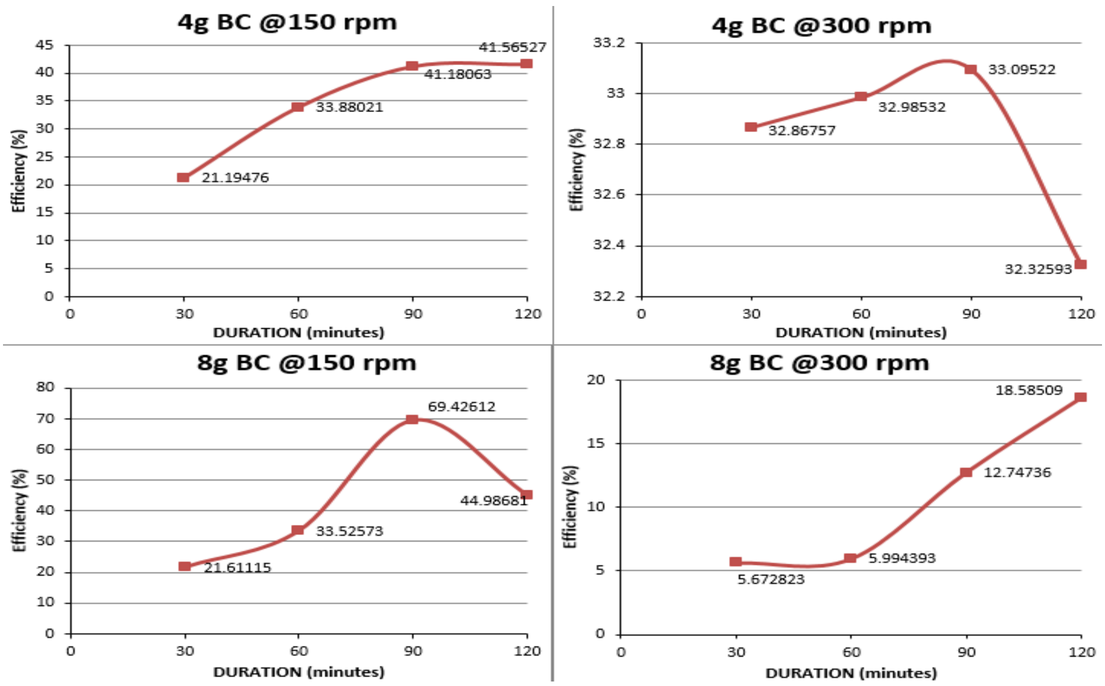

Fig.9.3 Duration v/s efficiency graphs of 445^{0}C CSBC on nitrate removal

3. Powdered activated charcoal

The graphical representation of the removal efficiency of the biochar at various proportions and at different revolutions per minute are shown in fig.9.4.

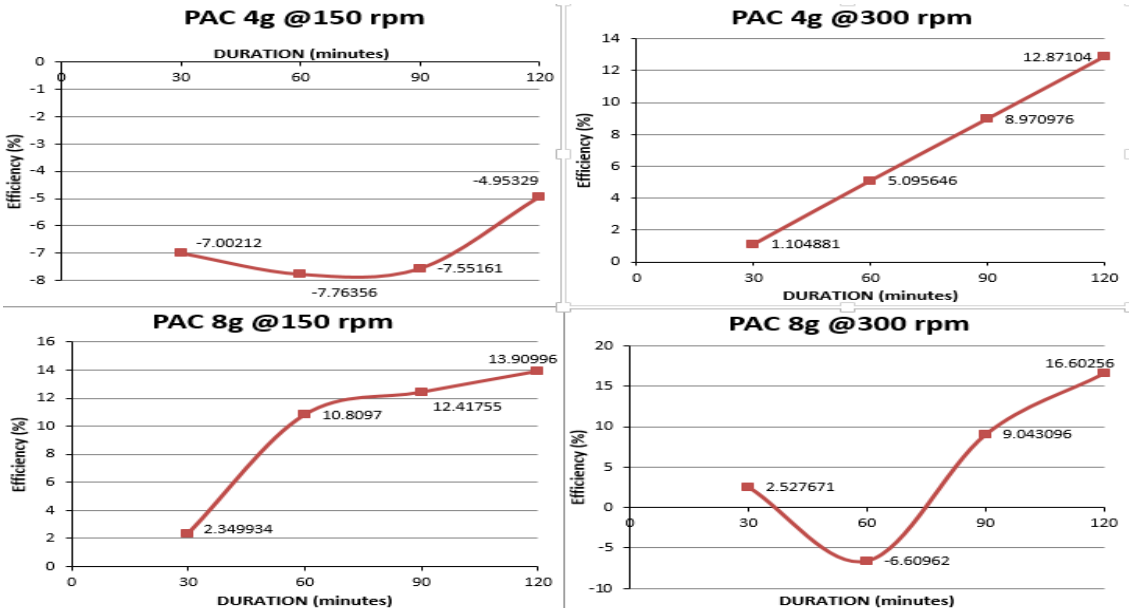

Fig.9.4 Duration v/s efficiency graphs of PAC on nitrate removal

4. Granular activated charcoal

The graphical representation of the removal efficiency of the biochar at various proportions and at different revolutions per minute are shown in fig.9.5.

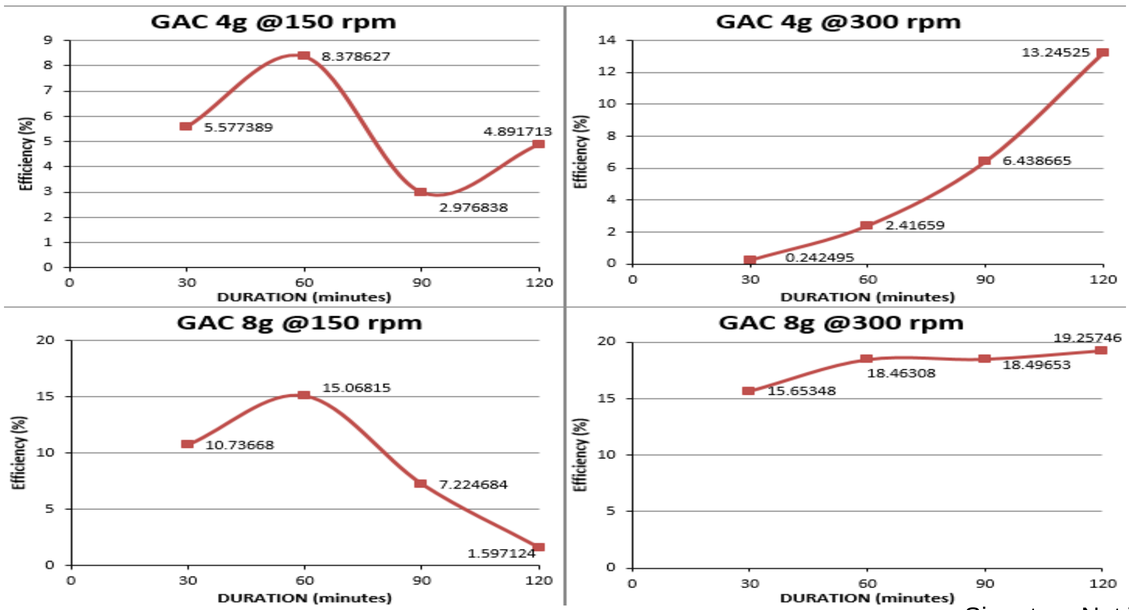

Fig.9.5 Duration v/s efficiency graphs of GAC on nitrate removal

9.1.5 Combination of Parameters

i) Duration v/s Efficiency

The comparison of duration v/s efficiency graph for the nitrate removal using various sorbents are given in fig. 9.6. The sorbents are 700^{0}C CSBC, 445^{0}C CSBC, PAC and GAC. The values at various revolutions per minute, contact periods and biochar dosages are compared here.

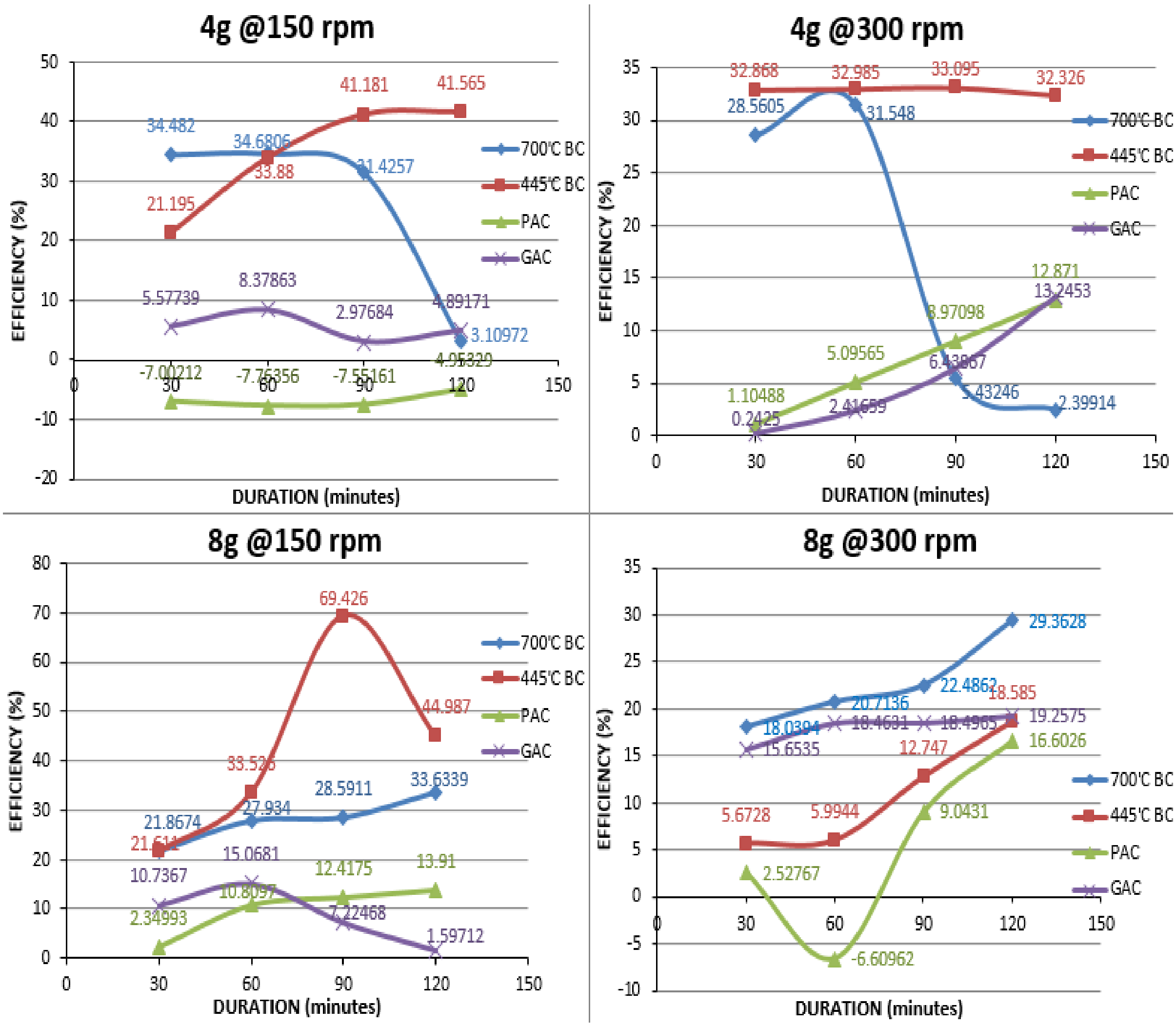

Fig.9.6 Duration v/s efficiency graphs of various sorbents for nitrate removal

ii) Duration v/s Change in pH

The comparison of duration v/s change in pH graph for the nitrate removal using various sorbents are given in fig. 9.7. The sorbents are 700^{0}C CSBC, 445^{0}C CSBC, PAC and GAC. The values at various revolutions per minute, contact periods and biochar dosages are compared here.

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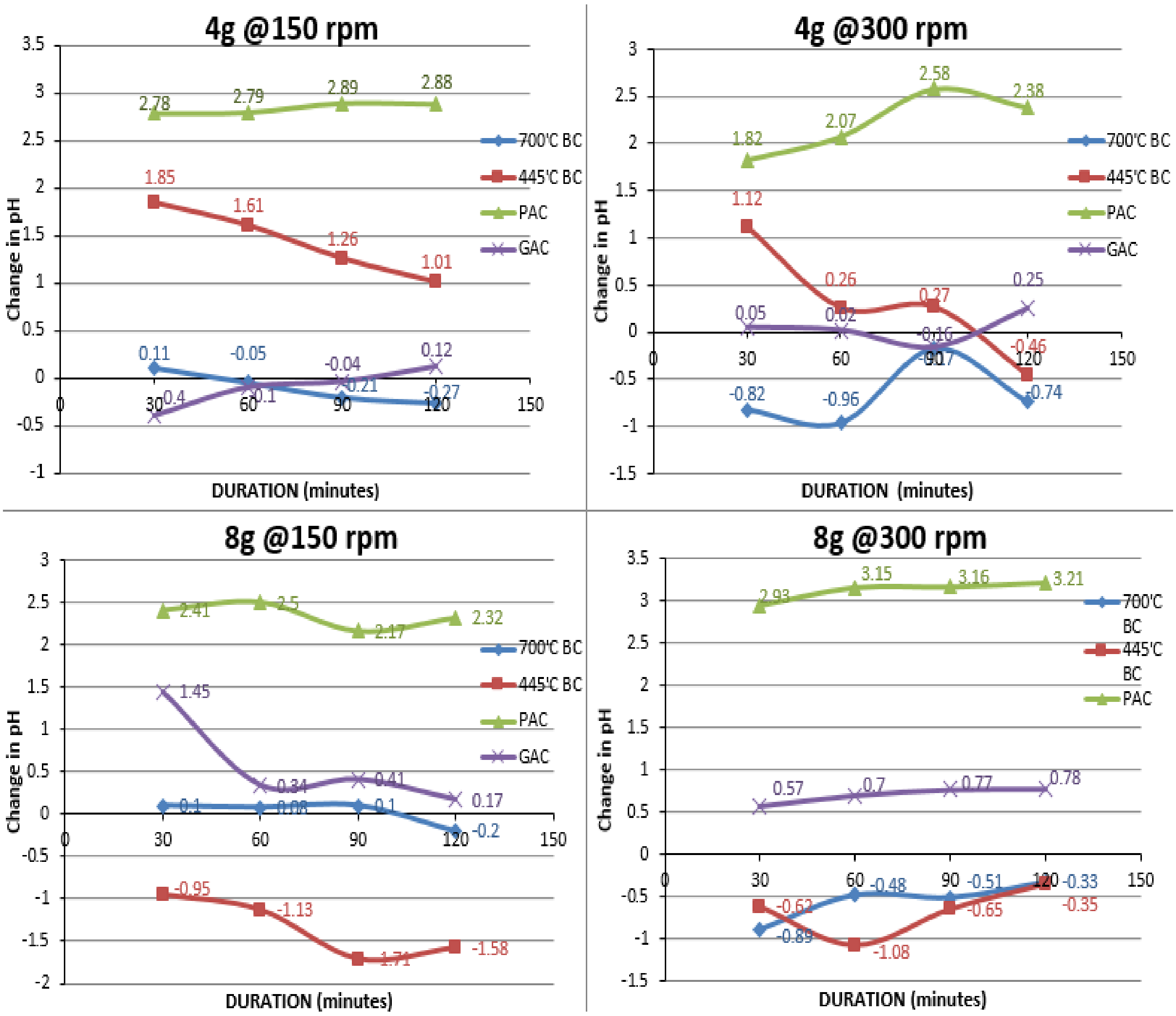

Fig.9.7 Duration v/s change in pH graphs of various sorbents for nitrate removal

9.1.6 Analysis of the Result

i) Effect of Dosage

Biochar has a porous structure that provides a large surface area for adsorption, allowing it to bind to pollutants such as heavy metals and chemical compounds. The results shows that higher dosages can result in greater adsorption capacity and improved removal rates.

ii) Effect of Contact Time

The contact time plays a crucial role in the effectiveness of the adsorption process and significantly affect the treatment efficiency. Initially, the adsorption rate is high as there are more available adsorption sites. Over time, the rate slows down as the concentration of the

adsorbate decreases in the wastewater. The adsorption process follows a typical pattern, starting with a rapid adsorption phase followed by a slower equilibrium phase.

iii) Effect of Revolutions per Minute

The number of revolutions influences the overall contaminant removal efficiency. Higher revolutions generate more turbulence and maintain the biochar particles in suspension, preventing settling or aggregation. Thus ensured a uniform contact between the biochar and the wastewater, enhancing adsorption efficiency. The biochar tends to settle quickly at 150 rpm, increasing the agitation to 300 rpm improved the overall effectiveness.

iv) Effect of pH

At lower pH levels, the biochar's surface becomes protonated, resulting in an increased positive charge. This enhanced positive charge can facilitate the electrostatic attraction between the biochar and the negatively charged nitrate ions, promoting adsorption. Therefore, the batch adsorption method using coconut shell biochar is expected to show higher nitrate removal efficiency at lower pH levels.

Conversely, at higher pH levels, the surface of the biochar becomes deprotonated, resulting in a decreased positive charge or even a negative charge. This change in surface charge reduces the electrostatic attraction between the biochar and the nitrate ions, potentially leading to a decrease in adsorption efficiency. Therefore, the batch adsorption method using coconut shell biochar may exhibit lower nitrate removal efficiency at higher pH levels.

The synthetic water treated with PAC and GAC shows high variation from initial pH, whereas much variations where not observed for synthetic water treated with CSBCs.

9.2 COLUMN EXPERIMENT

9.2.1 General

In chemistry, Column chromatography is a technique which is used to separate a single chemical compound from a mixture dissolved in a fluid. Column chromatography separates substances based on differential adsorption of compounds to the adsorbent as the compounds move through the column at different rates which allows them to get separated in fractions. This technique can be used on a small scale as well as large scale to purify materials that can

be used in future experiments. This method is a type of adsorption chromatography technique. Column absorption treatment using biochar offers a sustainable and cost-effective approach for removing various pollutants from water or liquid streams. Its versatility, combined with the renewable nature of biochar, makes it an attractive option for water treatment applications and environmental remediation.

9.2.2 Apparatus Required

- Glass column
- Mobile phase
- Stationary phase
- Filter paper
- Glass filter
- Sorbent
- Beakers
- Funnel
- Tray

9.2.3 Procedure

- Take a clean glass column.
- Keep the fine filter and the Whatman filter paper at the bottom of the glass column.
- Fill sorbents (700^0 C coconut shell biochar, 445^0C coconut shell biochar, powdered activated charcoal and granular activated charcoal) in the column at various bed heights of 0.5cm, 1cm, 1.5cm, 2cm and 2.5cm for different trials.
- Fill the top of the column with Whatman filter paper and a perforated glass filter.
- Feed the effluent sample from the top of the glass column and collect the effluent sample from the bottom. The schematic diagram and the conduction of column experiment are shown in fig.9.8.
- Collect the samples of each set of experiment and store it in a small volumetric flasks.
- The sample is undergone for tests for various parameters like pH and Chemical Oxygen Demand (COD).
- Determine the concentration of the effluent using UV-Visible Double Beam Spectrophotometer.

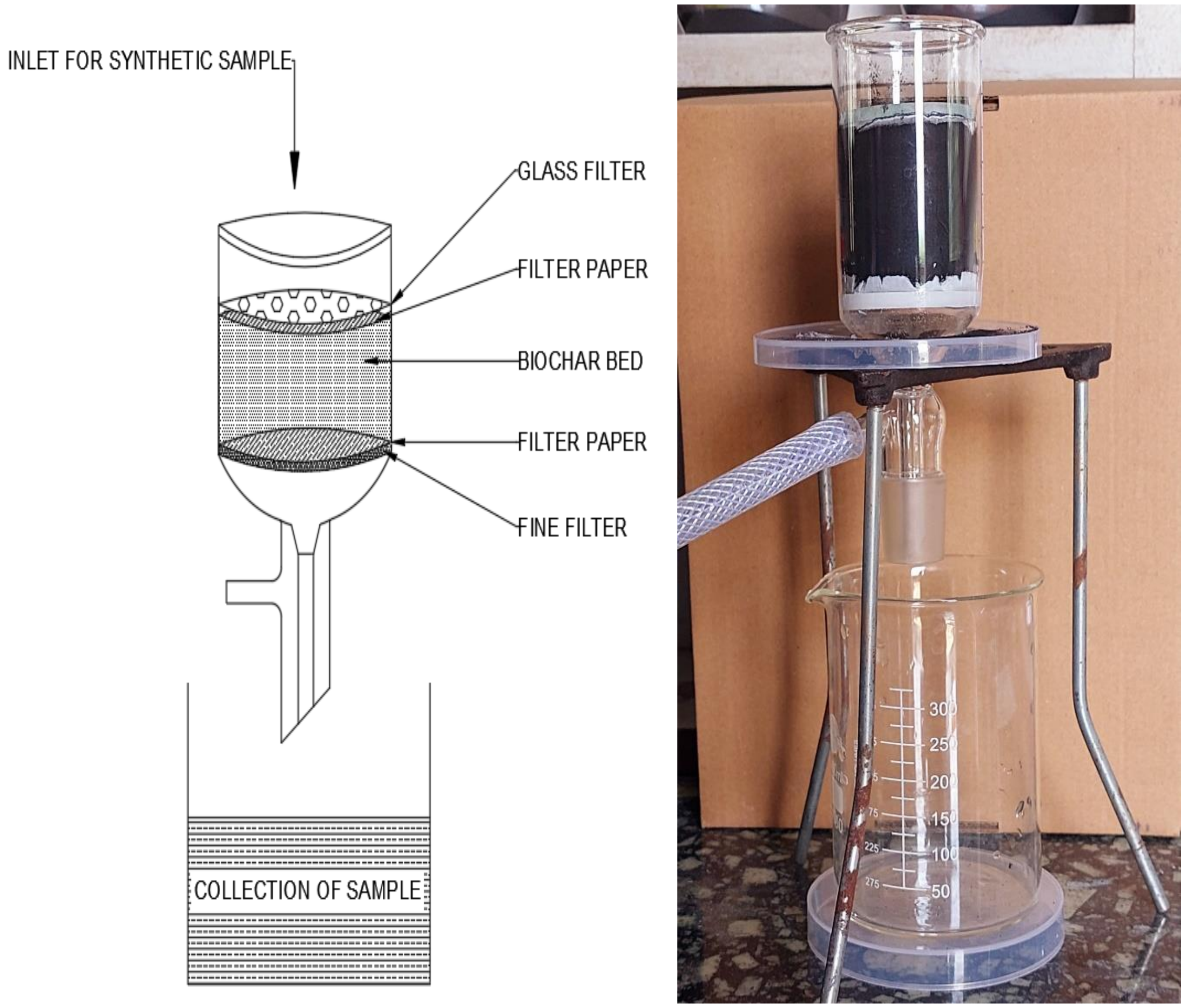

Fig. 9.8 Schematic diagram and conduction of column test

9.2.4 Result

i) Nitrate column experiment

The obtained results of the column experiment to check the nitrate removal efficiency of coconut shell biochars, powdered activated charcoal and granular activated charcoal are shown in figures.

1. Coconut Shell Biochar, 700°C at 2hrs 7mins

CSBC pyrolyzed at 700^{0}C were used to remove nitrate from the synthetic sample and various results were obtained. Fig.9.9 shows the bed height v/s concentration graph for nitrate removal using 700^{0} C CSBC. Fig.9.10 shows the bed height v/s pH graph, bed height v/s efficiency graph is given in fig.9.11 and bed height v/s COD graph is shown in fig.9.12.

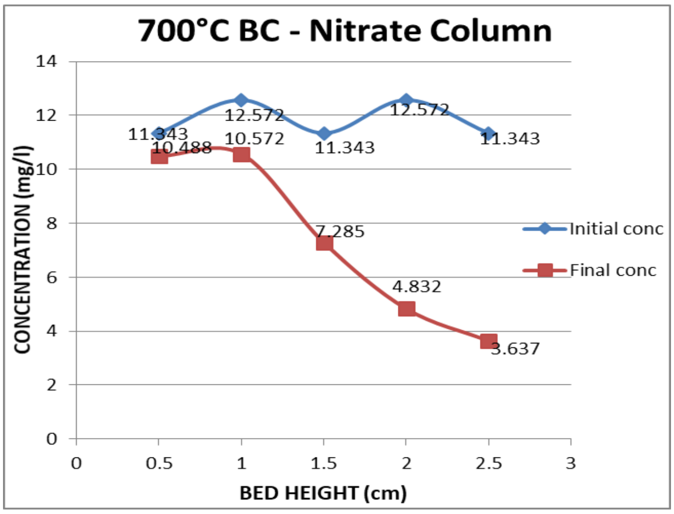

Fig.9.9 Bed height v/s concentration graph for nitrate removal using 700^0 C CSBC

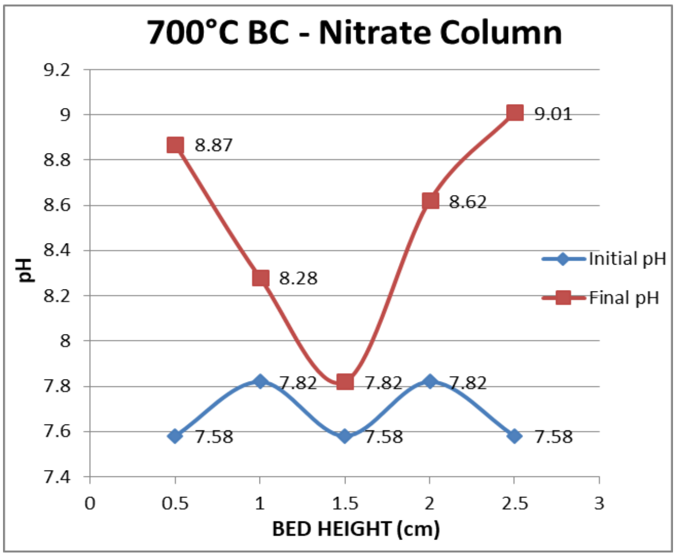

Fig.9.10 Bed height v/s pH graph for nitrate removal using 700^0C CSBC

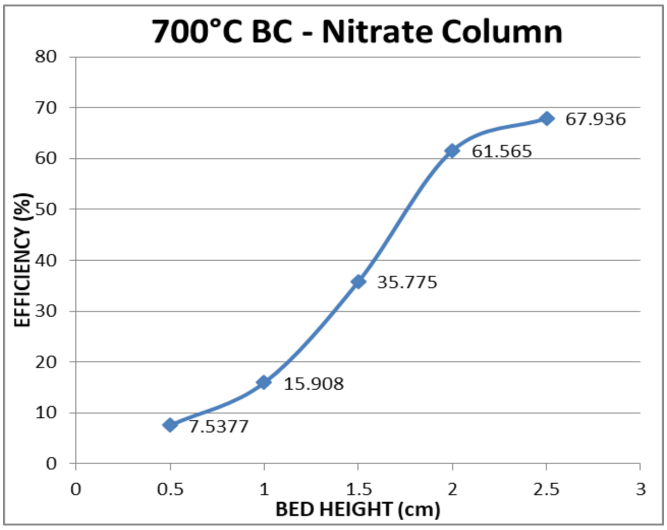

Fig.9.11 Bed height v/s efficiency graph for nitrate removal using 700^0C CSBC

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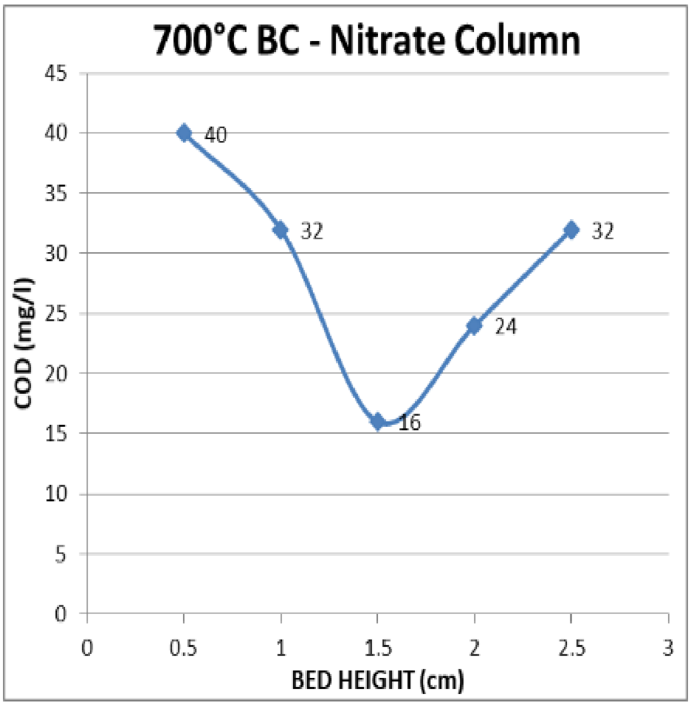

Fig.9.12 Bed height v/s COD graph for nitrate removal using 700^0C CSBC

2. Coconut Shell Biochar, 445°C at 2hrs 7mins

CSBC pyrolyzed at 445^0C were used to remove nitrate from the synthetic sample and various results were obtained. Fig.9.13 shows the bed height v/s concentration graph. Fig.9.14 shows the bed height v/s pH graph and bed height v/s efficiency graph is given in fig.9.15.

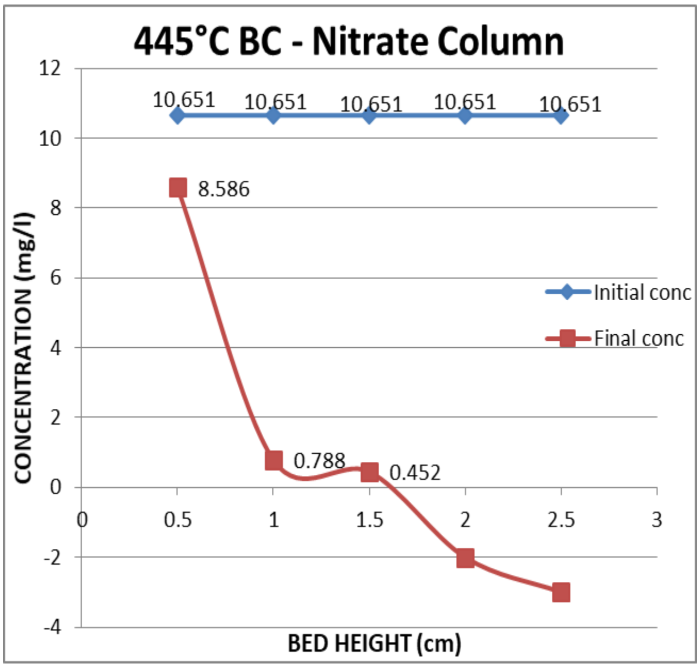

Fig.9.13 Bed height v/s concentration graph for nitrate removal using 445^0C CSBC

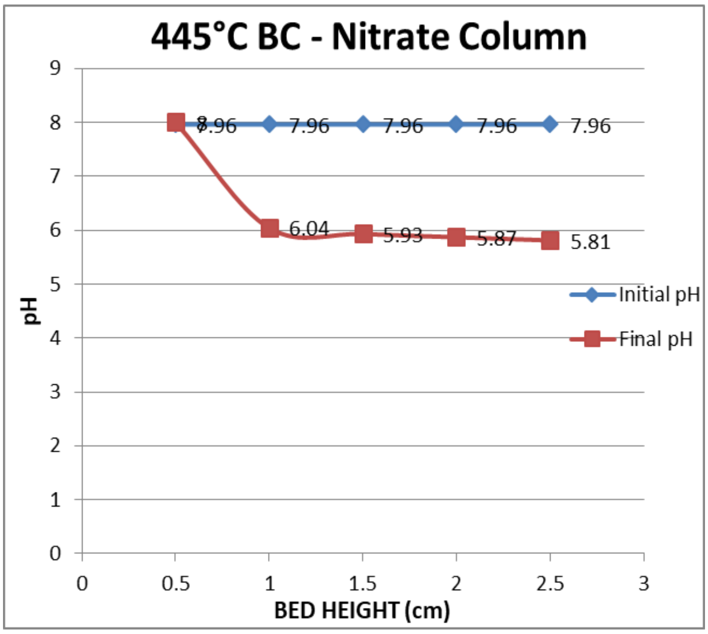

Fig.9.14 Bed height v/s pH graph for nitrate removal using 445^{0}C CSBC

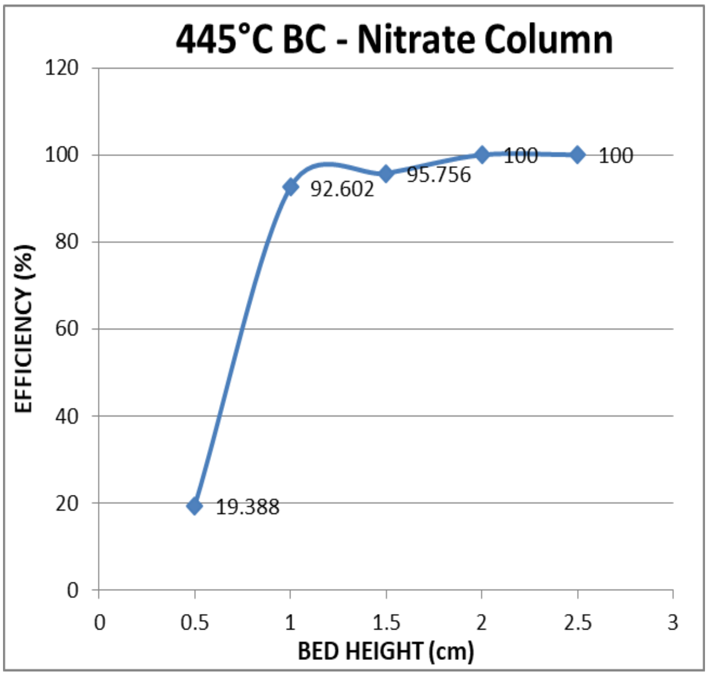

Fig.9.15 Bed height v/s efficiency graph for nitrate removal using 445^{0}C CSBC

3. Powdered activated charcoal

Powdered activated charcoal were used to remove nitrate from the synthetic sample and various results were obtained. Fig.9.16 shows the bed height v/s concentration graph. Fig.9.17 shows the bed height v/s pH graph, bed height v/s efficiency graph is given in fig.9.18 and bed height v/s COD graph is shown in fig.9.19.

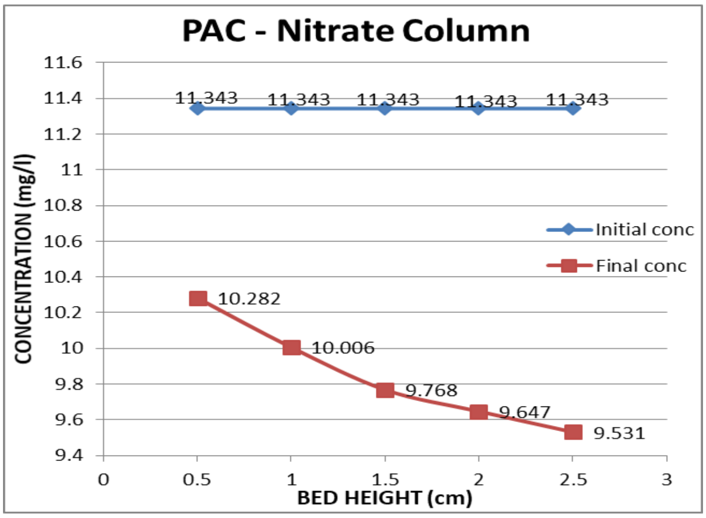

Fig.9.16 Bed height v/s concentration graph for nitrate removal using PAC

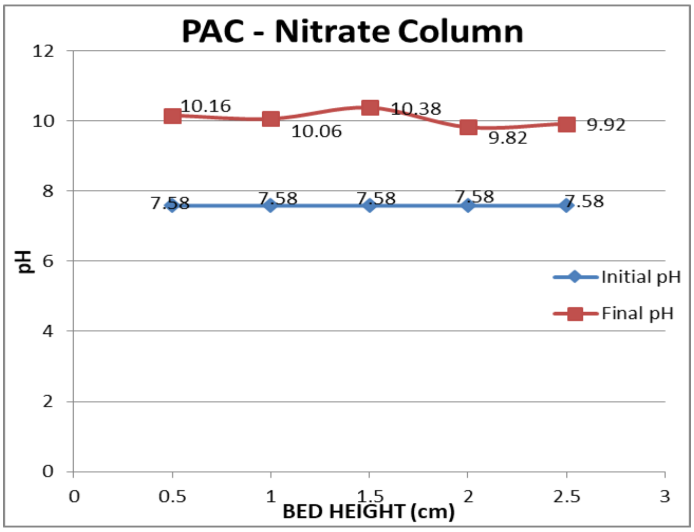

Fig.9.17 Bed height v/s pH graph for nitrate removal using PAC

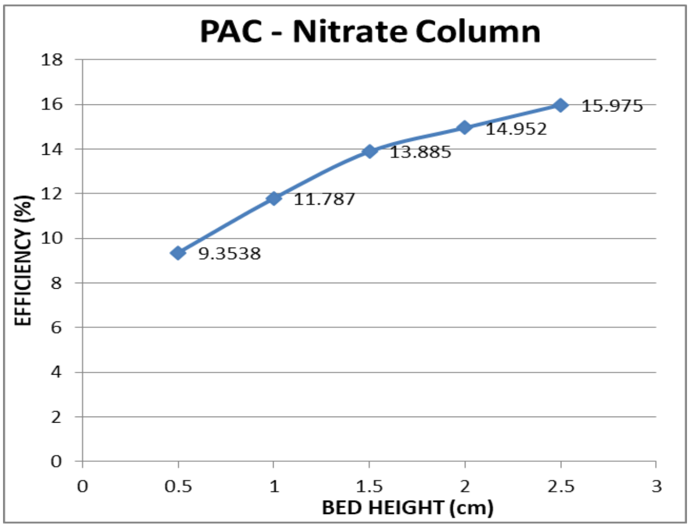

Fig.9.18 Bed height v/s efficiency graph for nitrate removal using PAC

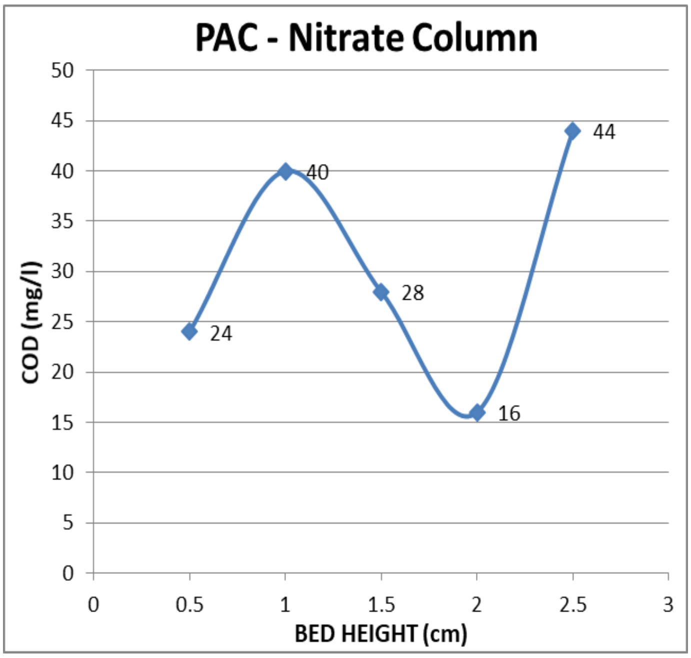

Fig.9.19 Bed height v/s COD graph for nitrate removal using PAC

4. Granular activated charcoal

Granular activated charcoal were used to remove nitrate from the synthetic sample and various results were obtained. Fig.9.20 shows the bed height v/s concentration graph. Fig.9.21 shows the bed height v/s pH graph and bed height v/s efficiency graph is given in fig.9.22.

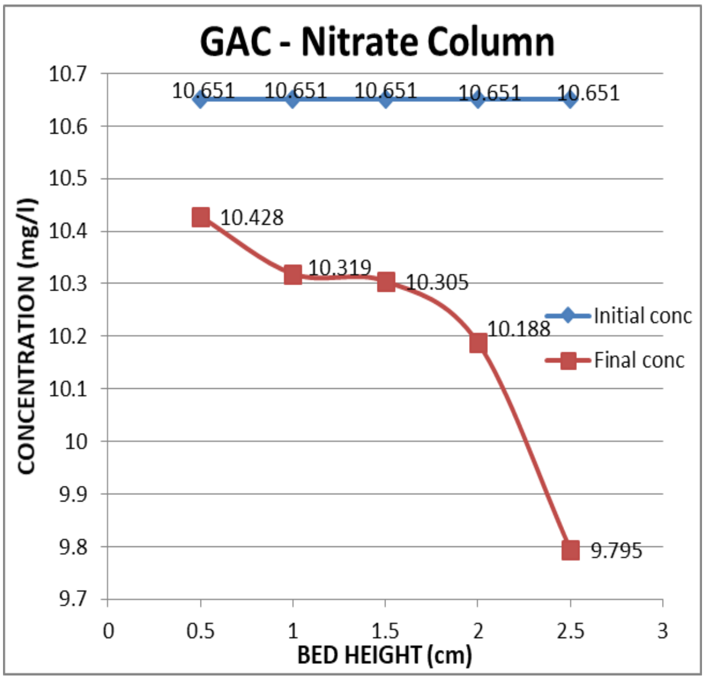

Fig.9.20 Bed height v/s concentration graph for nitrate removal using GAC

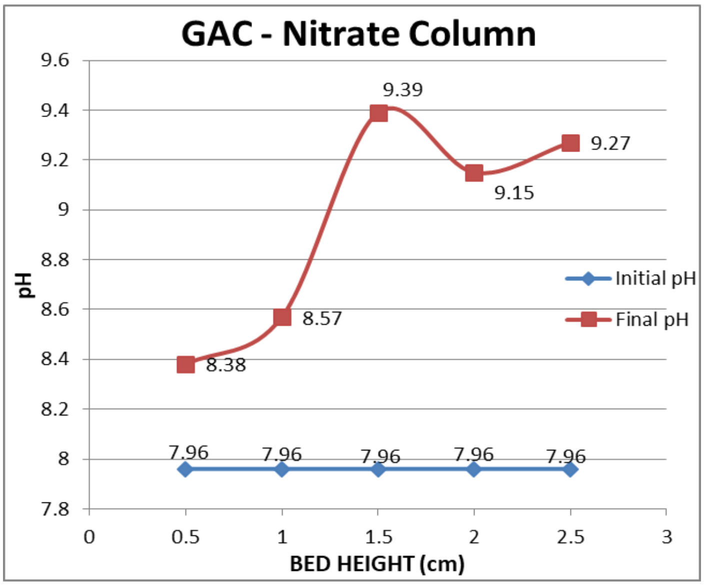

Fig.9.21 Bed height v/s pH graph for nitrate removal using GAC

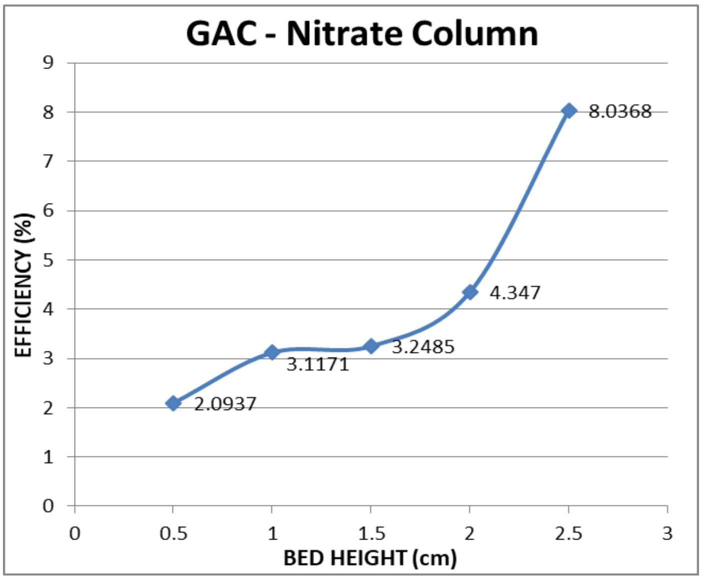

Fig.9.22 Bed height v/s efficiency graph for nitrate removal using GAC

ii) Phosphate Column Experiment

The obtained results of the column experiment to check the phosphate removal efficiency of coconut shell biochars, powdered activated charcoal carbon and granular activated charcoal are shown in figures.

1. Coconut Shell Biochar, 700°C at 2hrs 23mins

CSBC pyrolyzed at 700^{0}C were used to remove phosphate from the synthetic sample and various results were obtained. Fig.9.23 shows the bed height v/s concentration graph. Fig.9.24 shows the bed height v/s pH graph and bed height v/s efficiency graph is given in fig.

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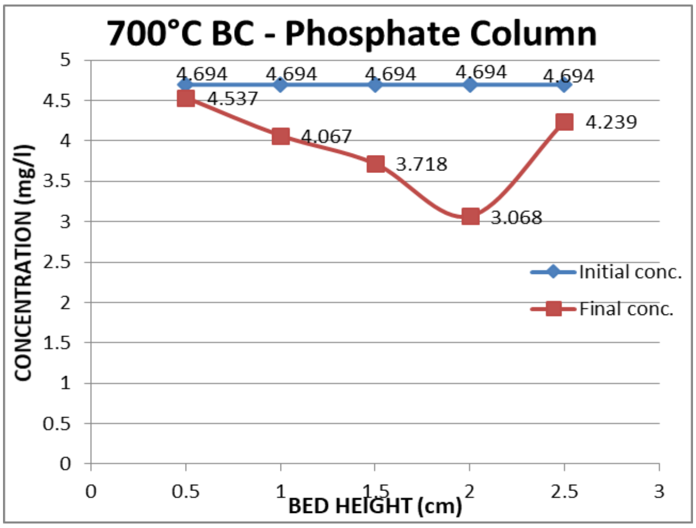

Fig.9.23 Bed height v/s concentration graph for phosphate removal using 700^0C CSBC

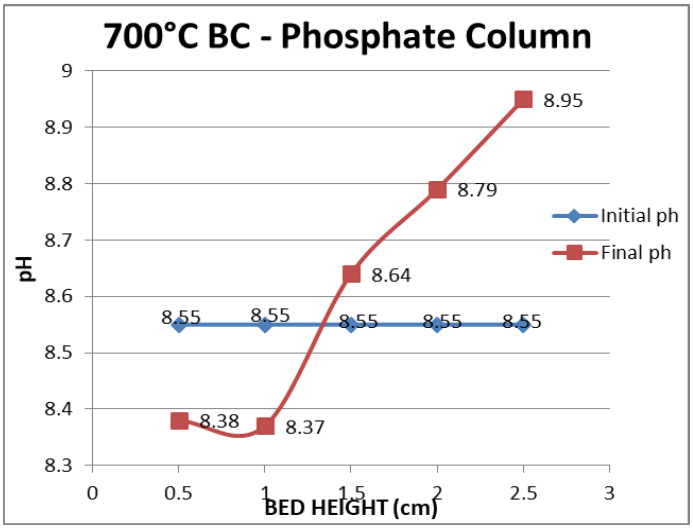

Fig.9.24 Bed height v/s pH graph for phosphate removal using 700^0C CSBC

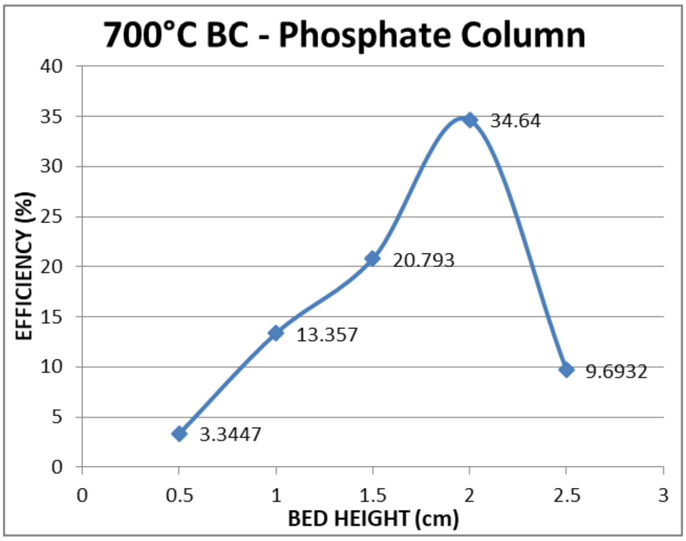

Fig.9.25 Bed height v/s efficiency graph for phosphate removal using 700^0C CSBC

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2. Coconut Shell Biochar, 445°C at 2hrs 7mins

CSBC pyrolyzed at 445^{0}C were used to remove phosphate from the synthetic sample and various results were obtained. Fig.9.26 shows the bed height v/s concentration graph. Fig.9.27 shows the bed height v/s pH graph and bed height v/s efficiency graph is given in fig.9.28.

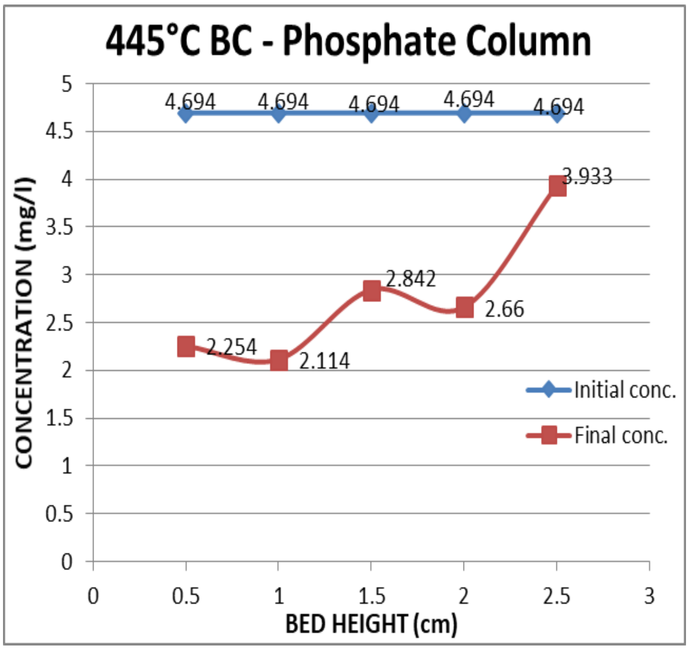

Fig.9.26 Bed height v/s concentration graph for phosphate removal using 445^{0}C CSBC

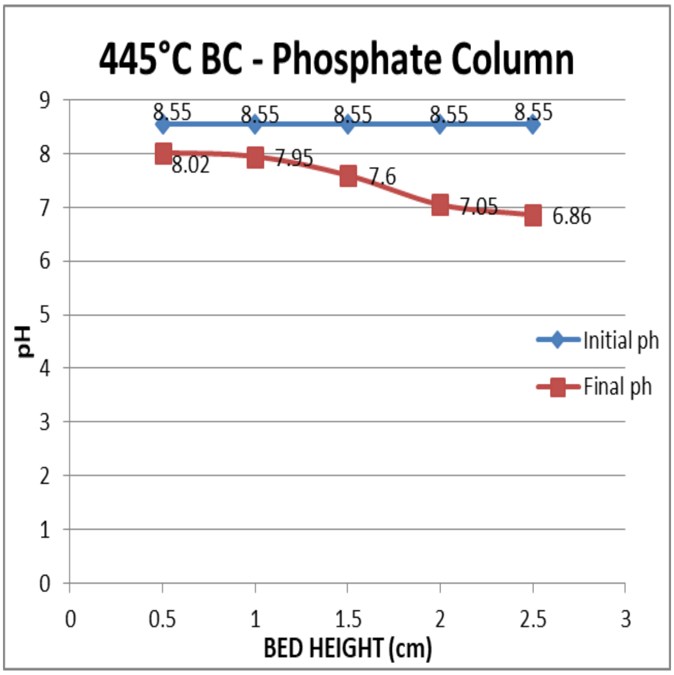

Fig.9.27 Bed height v/s pH graph for phosphate removal using 445^{0}C CSBC

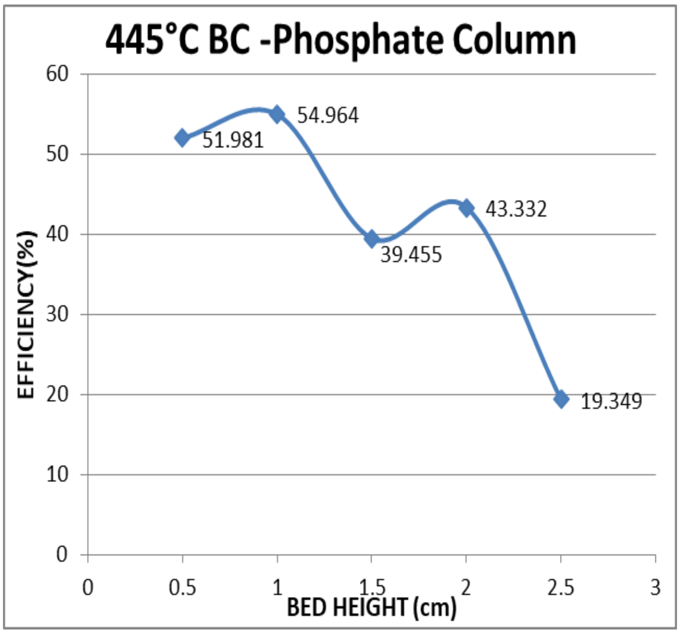

Fig.9.28 Bed height v/s efficiency graph for phosphate removal using 445^{0}C CSBC

3. Powdered activated charcoal

PAC were used to remove phosphate from the synthetic sample and various results were obtained. Fig.9.29 shows the bed height v/s concentration graph. Fig.9.30 shows the bed height v/s pH graph and bed height v/s efficiency graph is given in fig.9.31.

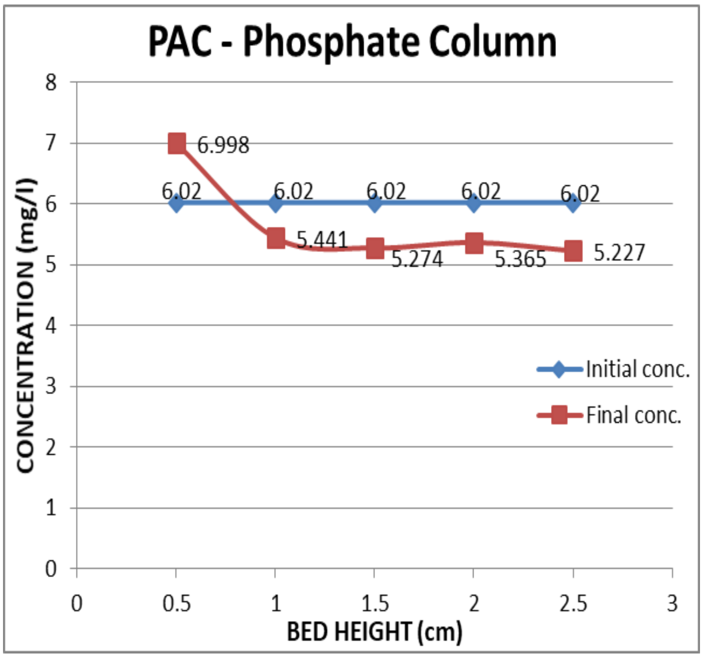

Fig.9.29 Bed height v/s concentration graph for phosphate removal using PAC

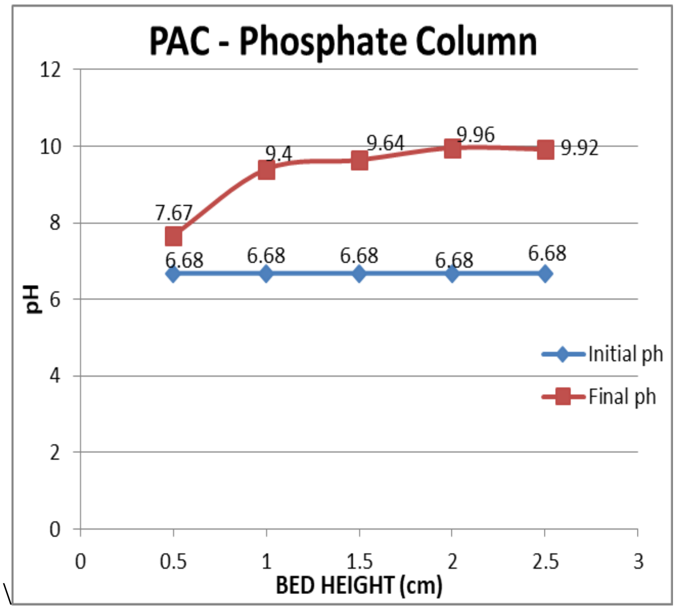

Fig.9.30 Bed height v/s pH graph for phosphate removal using PAC

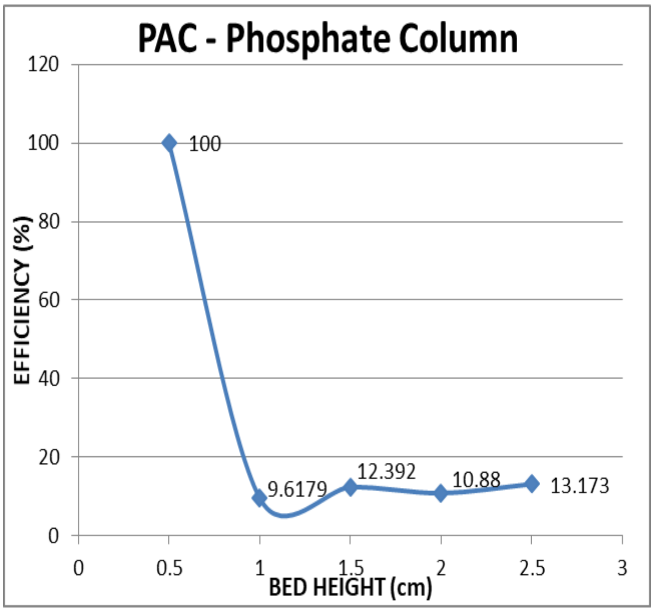

Fig.9.31 Bed height v/s efficiency graph for phosphate removal using PAC

4. Granular activated charcoal

GAC were used to remove phosphate from the synthetic sample and various results were obtained. Fig.9.32 shows the bed height v/s concentration graph. Fig.9.33 shows the bed height v/s pH graph and bed height v/s efficiency graph is given in fig.9.34.

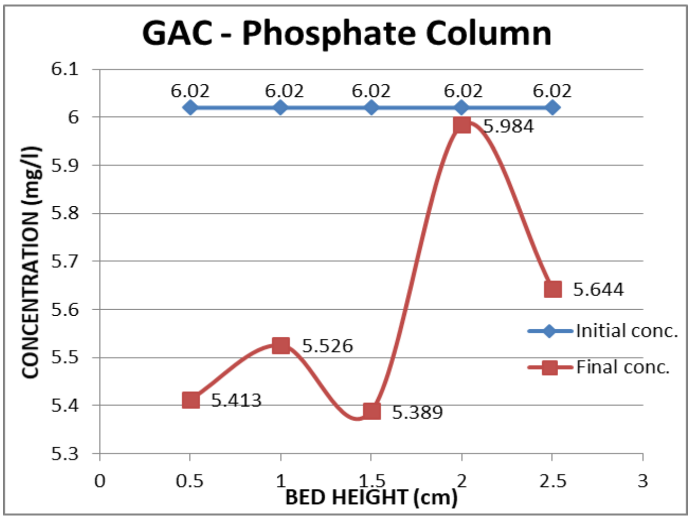

Fig.9.32 Bed height v/s concentration graph for phosphate removal using GAC

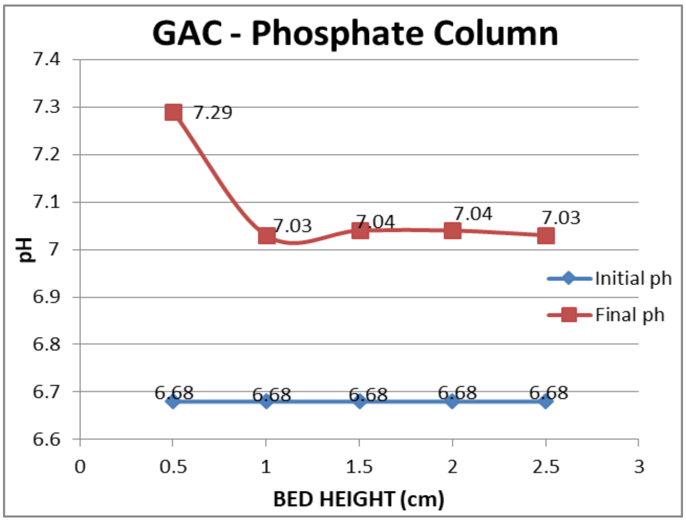

Fig.9.33 Bed height v/s pH graph for phosphate removal using GAC

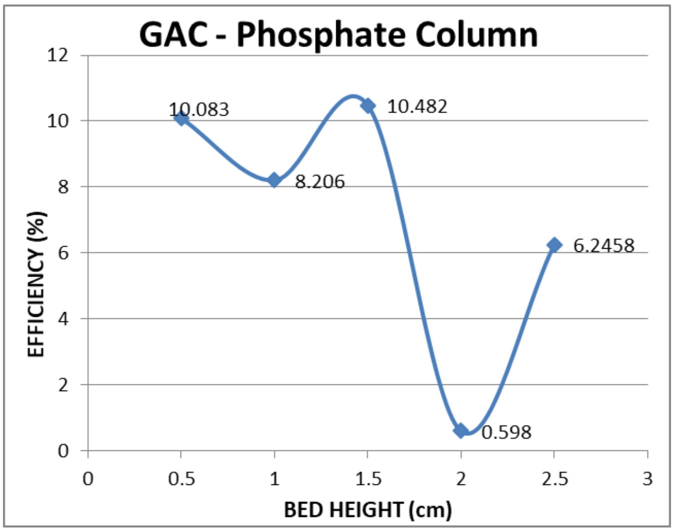

Fig.9.34 Bed height v/s efficiency graph for phosphate removal using GAC

9.2.5 Combination of Parameters

i) Bed Height v/s Efficiency

The comparison of bed height v/s efficiency graph for the nitrate removal and phosphate removal using various sorbents are given in fig. 9.35 and fig. 9.36 respectively. The sorbents are 700^{0}C CSBC, 445^{0}C CSBC, PAC and GAC. The values at various bed heights are compared here.

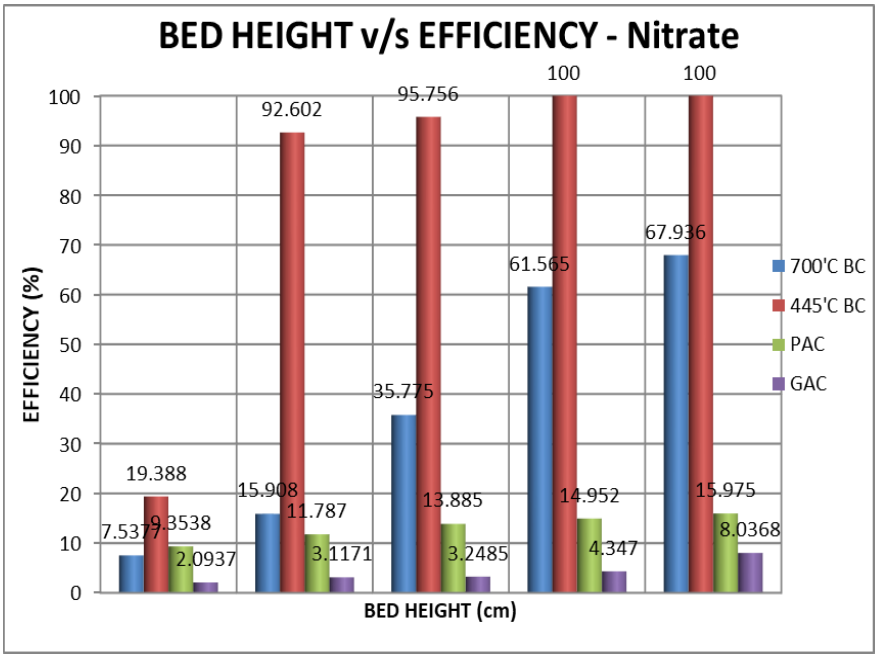

Fig.9.35 Bed height v/s efficiency graph of various sorbents for nitrate removal

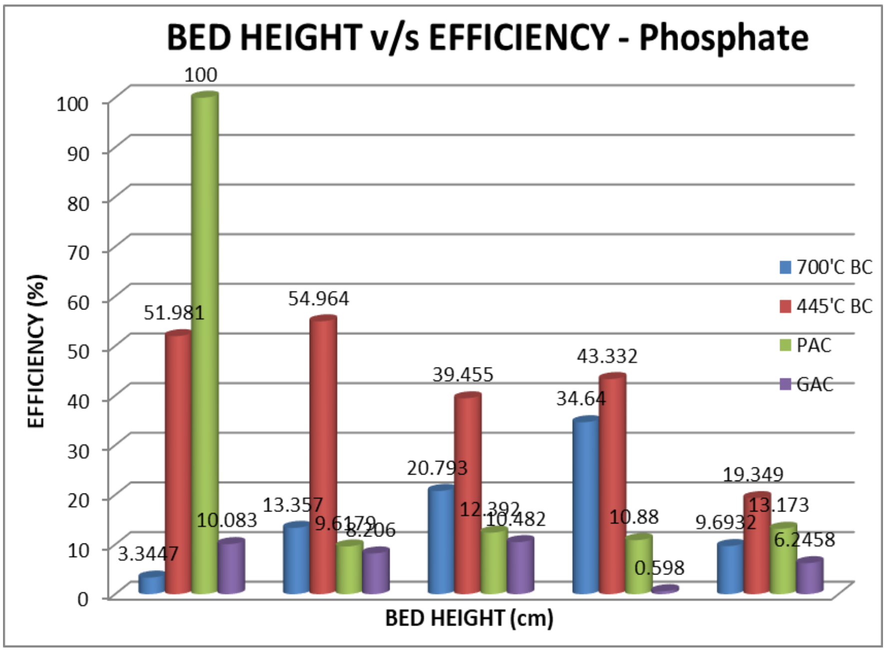

Fig.9.36 Bed height v/s efficiency graph of various sorbents for phosphate removal

ii) Bed Height v/s Change in pH

The comparison of bed height v/s change in pH graph for the nitrate removal and phosphate removal using various sorbents are given in fig. 9.37 and fig. 9.38 respectively. The sorbents are 700^{0}C CSBC, 445^{0}C CSBC, PAC and GAC. The values at various bed heights are compared here.

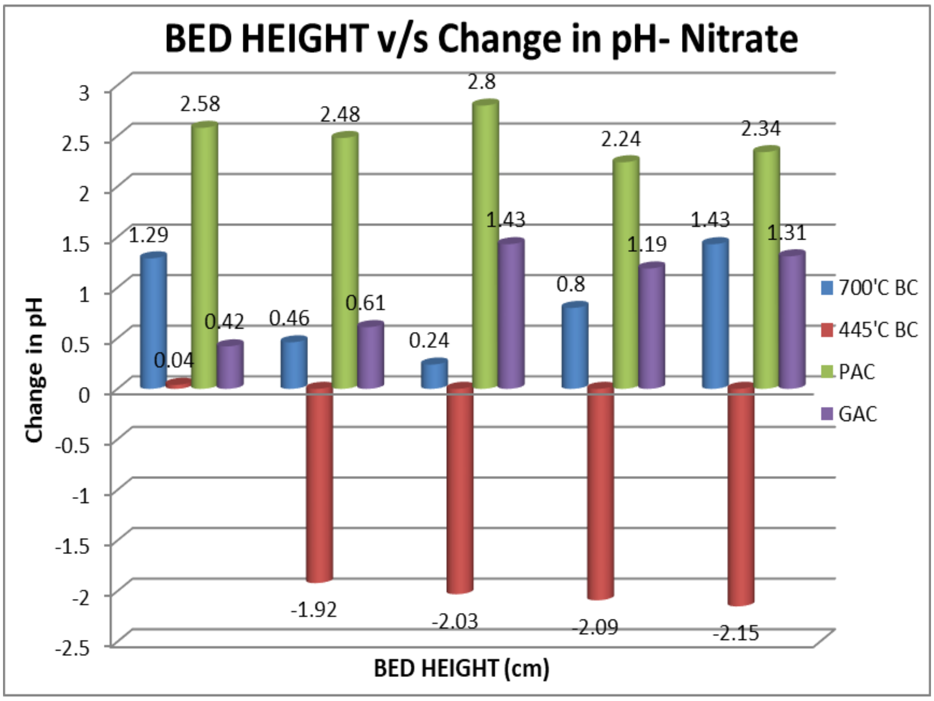

Fig.9.37 Bed height v/s change in pH graph of various sorbents for nitrate removal

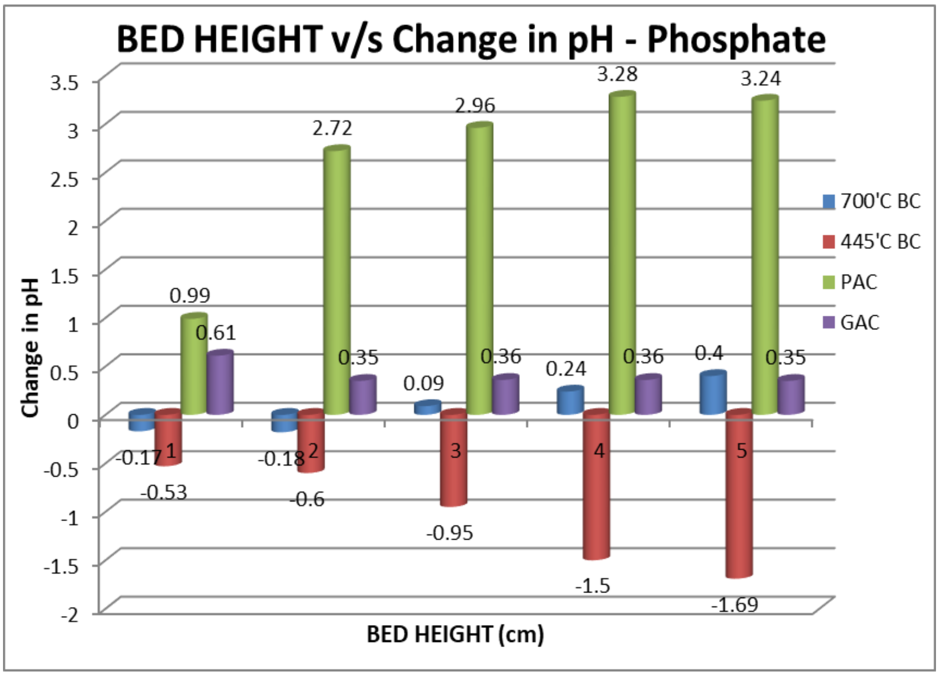

Fig.9.38 Bed height v/s Change in pH graph of various sorbents for phosphate removal

9.2.6 Analysis of the Result

i) Effect of Bed Height

The bed height directly affects the adsorption capacity of the biochar column. A greater bed height provides a larger surface area for adsorption, allowing more contaminants to come into contact with the biochar. As a result, a taller biochar bed accommodate a higher concentration of contaminants and potentially provide a higher adsorption capacity as compared to that of small bed height.

ii) Effect of pH

The pH of the solution plays a significant role in the column absorption treatment using biochar for the removal of nitrate and phosphate from contaminated water. The adsorption capacity of biochar for nitrate and phosphate ions can vary with pH. In general, at a neutral pH, biochar exhibits good adsorption capacity for both nitrate and phosphate. However, as the pH deviates from neutral, the adsorption capacity is affected.

The synthetic water treated with PAC and GAC shows high variation from initial pH, whereas much variations where not observed for synthetic water treated with CSBCs.

9.3 FUTURE SCOPE

Although the project's timeline may pose limitations on its comprehensive completion, it is planned to conduct tests on two different methods of contaminant removal: batch adsorption and column absorption treatment using water hyacinth and wood chips biochars. The primary focus of these experiments is to assess the efficiency of these materials in removing contaminants, specifically nitrate, phosphate and cadmium from water sources.

In the batch adsorption method, controlled laboratory tests will be conducted by introducing predetermined quantities of water hyacinth and wood chips biochar to water samples containing the targeted contaminants. The samples will be agitated and allowed to interact for a specified duration to facilitate adsorption. Subsequently, the concentrations of the contaminants in the water will be measured before and after the adsorption process to evaluate the effectiveness of the materials.

In addition to the batch adsorption method, a column absorption treatment method will be implemented. This method involves passing contaminated water through columns packed with water hyacinth and wood chips biochar. The water will flow through the column at a predetermined rate, allowing the materials to adsorb the targeted contaminants. Samples collected at various stages of the column will be analyzed to determine the extent of contaminant removal.

While the complete assessment of these methods for the removal of nitrate, phosphate, and cadmium is not guaranteed due to time constraints, the project aims to provide valuable insights into the effectiveness of water hyacinth and wood chips biochar as potential solutions for water contamination. These findings can serve as a basis for further research and development in this field.

CHAPTER 10

CONCLUSION

In conclusion, the project focused on evaluating the removal efficiency of coconut shell biochar for nitrate and phosphate contaminants in contaminated water. The project demonstrated that coconut shell biochar has the potential to effectively remove nitrate, while it is less effective in removing phosphate from contaminated water. The biochar exhibited significant adsorption capacity for these contaminants due to its porous structure and high surface area. The project found that the removal efficiency of nitrate and phosphate was influenced by various factors such as contact time, revolutions per minute, initial contaminant concentration, bed height and biochar dosage. Overall, the project contributes to the understanding of coconut shell biochar as a promising adsorbent for the removal of nitrate from water. Through our extensive experimentation and analysis, we have determined that the removal efficiency of nitrate is more effective compared to phosphate using coconut shell biochar.

- Effects on nitrate column method

A taller biochar bed accommodate a higher concentration of contaminants and potentially provide a higher adsorption capacity as compared to that of small bed height. The synthetic water treated with PAC and GAC shows high variation from initial pH, whereas much variations where not observed for synthetic water treated with CSBCs.

- Effects on phosphate column method

CSBC doesn’t show much effectiveness for phosphate removal. This may be due to the presence some other phosphate compounds present in the coconut shell biochar.

- Effects on nitrate batch method

Higher revolutions enhances the adsorption efficiency. The removal efficiency is increased with longer contact times and higher biochar dosages.

- Comparison of CSBC with PAC and GAC

Our findings indicate that coconut shell biochar demonstrates notable effectiveness in removing contaminants during both the batch and column absorption treatment methods. These results suggest that coconut shell biochar could potentially outperform powdered and granular activated charcoal in terms of removal efficiency. However, further comprehensive analysis and experimentation are required to ascertain and validate these promising results.

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APPENDIX

Table 1: Efficiency of CSBC 700°C at 2hrs 7mins on removing nitrate (column method)

Bed height (cm)	Initial pH of sample	Final pH of sample	COD (mg/l)	Removal efficiency (%)
0.5	7.58	8.87	40	7.537688
1	7.82	8.28	32	15.90837
1.5	7.58	7.82	16	35.77537
2	7.82	8.62	24	61.56538
2.5	7.58	9.01	32	67.93617

Table 2: Efficiency of CSBC 445°C at 2hrs 23mins on removing nitrate (column method)

Bed height (cm)	Initial pH of sample	Final pH of sample	Removal efficiency (%)
0.5	7.96	8	19.38785
1	7.96	6.04	92.60163
1.5	7.96	5.93	95.75627
2	7.96	5.87	-
2.5	7.96	5.81	-

Table 3: Efficiency of PAC on removing nitrate (column method)

Bed height (cm)	Initial pH of sample	Final pH of sample	COD (mg/l)	Removal efficiency (%)
0.5	7.58	10.16	24	9.353786
1	7.58	10.06	40	11.78701
1.5	7.58	10.38	28	13.88522
2	7.58	9.82	16	14.95195
2.5	7.58	9.92	44	15.97461

Table 4: Efficiency of GAC on removing nitrate (column method)

Bed height (cm)	Initial pH of sample	Final pH of sample	Removal efficiency (%)
0.5	7.96	8.38	2.0937
1	7.96	8.57	3.117078
1.5	7.96	9.39	3.248521
2	7.96	9.15	4.34701
2.5	7.96	9.27	8.03680[illegible]

Table 5: Efficiency of CSBC 700°C at 2hrs 7mins on removing phosphate (column method)

Bed height (cm)	Initial pH of sample	Final pH of sample	Removal efficiency (%)
0.5	8.55	8.38	3.344695
1	8.55	8.37	13.35748
1.5	8.55	8.64	20.7925
2	8.55	8.79	34.63997
2.5	8.55	8.95	9.693225

Table 6: Efficiency of CSBC 445°C at 2hrs 23mins on removing phosphate (column method)

Bed height (cm)	Initial pH of sample	Final pH of sample	Removal efficiency (%)
0.5	8.55	8.02	51.98125
1	8.55	7.95	54.96378
1.5	8.55	7.6	39.45462
2	8.55	7.05	43.33191
2.5	8.55	6.86	19.3491

Table 7: Efficiency of PAC on removing phosphate (column method)

Bed height (cm)	Initial pH of sample	Final pH of sample	Removal efficiency (%)
0.5	6.68	7.67	100
1	6.68	9.4	9.61794
1.5	6.68	9.64	12.392
2	6.68	9.96	10.8804
2.5	6.68	9.92	13.1728

Table 8: Efficiency of GAC on removing phosphate (column method)

Bed height (cm)	Initial pH of sample	Final pH of sample	Removal efficiency (%)
0.5	6.68	7.29	10.0831
1	6.68	7.03	8.20598
1.5	6.68	7.04	10.4817
2	6.68	7.04	0.59801
2.5	6.68	7.03	6.24585

Table 9: Efficiency of CSBC 700°C at 2hrs 7mins on removing nitrate (batch method)

Weight (gm)	Revolutions per minute	Initial pH of sample	Contact period	Final pH of sample	Removal efficiency (%)
4	150	8.16	30 mins	8.27	34.48197
		8.16	60 mins	8.11	34.68062
		8.16	90 mins	7.95	31.42573
		8.16	120 mins	7.89	3.109719
4	300	8.16	30 mins	7.34	28.56051
		8.16	60 mins	7.2	31.54798
		8.16	90 mins	7.99	5.432457
		8.16	120 mins	7.42	2.399144
8	150	8.16	30 mins	8.26	21.86736
		8.16	60 mins	8.24	27.93399
		8.16	90 mins	8.26	28.59108
		8.16	120 mins	7.96	33.63386
8	300	8.16	30 mins	7.27	18.03943
		8.16	60 mins	7.68	20.71363
		8.16	90 mins	7.65	22.48625
		8.16	120 mins	7.83	19.36278

Table 10: Efficiency of CSBC 445°C at 2hrs 23mins on removing nitrate (batch method)

Weight (gm)	Revolutions per minute	Initial pH of sample	Contact period	Final pH of sample	Removal efficiency (%)
4	150	7.62	30 mins	9.47	21.19476
		7.62	60 mins	9.23	33.88021
		7.62	90 mins	8.88	41.18063
		7.62	120 mins	8.63	41.56527
4	300	7.62	30 mins	8.74	32.86757
		7.62	60 mins	7.88	32.98532
		7.62	90 mins	7.89	33.09522
		7.62	120 mins	7.16	32.32593
8	150	7.88	30 mins	6.93	21.61115
		7.88	60 mins	6.75	33.52573
		7.88	90 mins	6.17	69.42612
		7.88	120 mins	6.3	44.98681
8	300	7.88	30 mins	7.26	5.672823
		7.88	60 mins	6.8	5.994393
		7.88	90 mins	7.23	12.74736
		7.88	120 mins	7.53	18.58509

Table 11: Efficiency of PAC on removing nitrate (batch method

Weight (gm)	Revolutions per minute	Initial pH of sample	Contact period	Final pH of sample	Removal efficiency (%)
4	150	7.62	30 mins	10.4	-7.00212
		7.62	60 mins	10.41	-7.76356
		7.62	90 mins	10.51	-7.55161
		7.62	120 mins	10.5	-4.95329
4	300	7.88	30 mins	9.7	1.104881
		7.88	60 mins	9.95	5.095646
		7.88	90 mins	10.46	8.970976
		7.88	120 mins	10.26	12.87104
8	150	7.88	30 mins	10.29	2.349934
		7.88	60 mins	10.38	10.8097
		7.88	90 mins	10.05	12.41755
		7.88	120 mins	10.2	13.90996
8	300	7.62	30 mins	10.55	2.527671
		7.62	60 mins	10.77	-6.60962
		7.62	90 mins	10.78	9.043096
		7.62	120 mins	10.83	16.60256

Table 12: Efficiency of GAC on removing nitrate (batch method)

Weight (gm)	Revolutions per minute	Initial pH of sample	Contact period	Final pH of sample	Removal efficiency (%)
4	150	6.86	30 mins	6.46	5.577389
		6.86	60 mins	6.76	8.378627
		6.86	90 mins	6.82	2.976838
		6.86	120 mins	6.98	4.891713
4	300	6.86	30 mins	6.91	0.242495
		6.86	60 mins	6.88	2.41659
		6.86	90 mins	6.7	6.438665
		6.86	120 mins	7.11	13.24525
8	150	6.86	30 mins	8.31	10.73668
		6.86	60 mins	7.2	15.06815
		6.86	90 mins	7.27	7.224684
		6.86	120 mins	7.03	1.597124
8	300	6.86	30 mins	7.43	15.65348
		6.86	60 mins	7.56	18.46308
		6.86	90 mins	7.63	18.49653
		6.86	120 mins	7.64	19.25746

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Ms. Hridya P	**Mr. Rojin P**	**Dr. Biju Mathew**
Assistant Professor	Assistant Professor	Professor & Head
Vimal Jyothi Engineering College	Vimal Jyothi Engineering College	Vimal Jyothi Engineering College
Chemperi, Kannur	Chemperi, Kannur	Chemperi, Kannur

Department of Civil Engineering * VJEC, Chemperi * Date.........

Signature Not Verified
Principal VJEC

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DEPARTMENT OF CIVIL ENGINEERING

VIMAL JYOTHI ENGINEERING COLLEGE, CHEMPERI

CERTIFICATE

This is to certify that the report entitled '**Flood vulnerability assessment of Sreekandapuram municipality and Payyavoor Panchayath using GIS**' submitted by '**Abhijith Jayan (VML19CE003), Aishwarya P K (VML19CE011), Akarsh M (VML19CE013), Anusree Ramachandran (VML19CE031) and Vaishnavi Suresh (VML19CE100)**' to the APJ Abdul Kalam Technological University in partial fulfillment of the requirement for the award of the Degree of Bachelor of Technology in Civil Engineering is a bonafide record of the project work carried out by them under our guidance and supervision. This report in any form has not been submitted to any University or Institute for any purpose.

Project Guide

22.06.23

Mr. ABHIJATH I P
Assistant Professor
Department of Civil Engineering
Vimal Jyothi Engineering College
Chemperi, Kannur

Project Coordinator

22/6/23

Ms. HRIDYA P
Assistant Professor
Department of Civil Engineering
Vimal Jyothi Engineering College
Chemperi, Kannur

Head of the Department

Place : VJEC Chemperi
Date : 27-06-2023

(Office seal)

Department of Civil Engineering
V.J.E.C. Chemperi

Signature Not Verified
Principal VJEC

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CERTIFICATE

This is to certify that the report entitled **'Identifying, Analysing And Treating Blackspots At Karivellur – Mele Chovva Road'** submitted by **Amal Jose(VML19CE017), Riya Jose(VML19CE080), Saikrishna T.O(VML19CE082), Tina Ravindran V(VML19CE098)** to the APJ Abdul Kalam Technological University in partial fulfillment of the requirements for the award of the Degree of Bachelor of Technology in Civil Engineering is a bonafide record of the project work carried out by her under my guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

Project Guide

23/06/23

Mr. LOGI N BOBY

Department of Civil Engineering

Vimal Jyothi Engineering College, Chemperi

Project Coordinator

23/6/23

Ms. HRIDYA

Department of Civil Engineering

Vimal Jyothi Engineering College, Chemperi

Head of the department

Place : VJEC Chemperi

Date : 23-06-2023

VIMAL JYOTHI ENGINEERING COLLEGE ★CHEMPERI-670632★
Dated.....................

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Signature Not Verified

Principal.VJEC

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CERTIFICATE

This is to certify that the report entitled **Land Use and Land Cover Mapping of Kannur District** submitted by **Muhammad Rasy PC** (VML19CE069), **Razeen Moosa V** (VML19CE078), **Sreelakshmi E** (VML19CE094), **Thanwi Rajeev** (VML19CE096) to the APJ Abdul Kalam Technological University in partial fulfillment of the B.Tech degree in Civil Engineering is a bonafide record of the project work carried out by them under our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

22.06.23

Mr. Abhijath I P
(Project Guide)
Assistant Professor
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22.06.23

Ms. Hridya P
(Project Coordinator)
Assistant Professor
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Place: VJEC Chemperi
Date: 21/06/2023

Head of the department

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Department of Civil Engineering ★ VJEC, Chemperi ★ Date

Signature Not Verified
Principal.VJEC

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DEPARTMENT OF CIVIL ENGINEERING

CERTIFICATE

This is to certify that the report entitled **"Morphometric and PCA based Watershed Prioritisation for the Anjarakandy River Basin Using Geospatial Technology"** submitted by **Ms. Anagha PremarajanV , Mr. Ansaf CP , Ms. Anupriya A , Ms. Nila KP , Mr. Zaidan Azad** to the APJ Abdul Kalam Technological University in partial fulfillment of the requirements for the award of the Degree of Bachelor of Technology in Civil Engineering is a bonafide record of the project work carried out by them under my/our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

23/6/23

Mrs. SHIMNA P
(Project Guide)
Assistant Professor
Department of Civil Engineering
Vimal Jyothi Engineering College
Chemperi

23/6/23

Mrs. HRIDYA P
(Project Coordinator)
Assistant Professor
Department of Civil Engineering
Vimal Jyothi Engineering College
Chemperi

Head of the Department

Place : VJEC chemperi
Date : 22-06-2023

VIMAL JYOTHI ENGINEERING COLLEGE
(Office seal)
Dated.........................
CHEMPERI-670 632

Signature Not Verified
Principal.VJEC

VIMAL JYOTHI ENGINEERING COLLEGE

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CERTIFICATE

This is to certify that the report entitled **"Numerical Analysis of Settlement of Centrally and Eccentrically Loaded Circular Footing on Geogrid- Reinforced Sand Using PLAXIS 2D"** submitted by **Anagha KP** (VML19CE019), **Anto Ronald Reji** (VML19CE027), **Dwithin Dileep** (VML19CE048), **Krishnapriya C** (VML19CE061) to the APJ Abdul Kalam Technological University in partial fulfillment of the B.Tech degree in Civil Engineering is a bonafide record of the project work carried out by them under our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

Project Guide	**Project Coordinator**	**Head Of Department**
22/6/2023	22/6/23	
Mrs. Aswathi K	**Mrs. Hridya p**	**Dr. Biju Mathew**
Assistant Professor	Assistant Professor	Professor and Head
Department of civil Engineering	Department of civil Engineering	Department of civil Engineering
Vimal Jyothi Engineering College	Vimal Jyothi Engineering College	Vimal Jyothi Engineering College
Chemperi	Chemperi	Chemperi

Department of Civil Engineering ★ VJEC, Chemperi ★ Date.........

Signature Not Verified

Principal.VJEC

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DEPARTMENT OF CIVIL ENGINEERING

VIMAL JYOTHI ENGINEERING COLLEGE, CHEMPERI

CERTIFICATE

This is to certify that the report entitled **'Reuse of Laundry Waste Water from Washing Machine'** submitted by **Aparna Ramesh (VML19CE032), Aryasree Ramachandran (VML19CE035), Neha Saseendran(VML19CE073), Rithin T Ramesh (VML19CE079),** to the APJ Abdul Kalam Technological University in partial fulfilment of the requirements for the award of the Degree of Bachelor of Technology in Civil Engineering is a bonafide record of the project work carried out them under our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

Project Guide	Project Coordinator	Head of Department
Ms. Sigi Thomas	**Mr. Rojin P**	**Dr. Biju Mathew**
Associate Professor	Assistant Professor	Professor and Head
Department of Civil Engineering	Department of Civil Engineering	Department of Civil Engineering
Vimal Jyothi Engineering College	Vimal Jyothi Engineering College	Vimal Jyothi Engineering College
Chemperi, Kannur	Chemperi, Kannur	Chemperi, Kannur

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CERTIFICATE

This is to certify that the project report entitled **'Seepage And Slope Stability Analysis of Karappuzha Earthen Dam Using GEOSTUDIO Software'** submitted by **'Sreeshma Govindan (VML19CE095), Sandra N (VML19CE084), Jishnu Santh (VML19CE056), Abhiram J.M (VML19CE005)'** to the APJ Abdul Kalam Technological University in partial fulfillment of the requirements for the award of the Degree of Bachelor of Technology in Civil Engineering is a bonafide record of the project work carried out by them under our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose

Project Guide

22/6/23

Ms. MARGARET ABRAHAM
Assistant Professor
Department of Civil Engineering
Vimal Jyothi Engineering College, Chemperi

Project Coordinator

22/6/23

Ms. HRIDYA P
Assistant professor
Department of Civil Engineering
Vimal Jyothi Engineering College, Chemperi

Head of the Department

Place : VJEC Chemperi
Date : 26-05-2023

(Office Seal)
Date............

Signature Not Verified
Principal VJEC

VIMAL JYOTHI ENGINEERING COLLEGE
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DEPARTMENT OF CIVIL ENGINEERING

CERTIFICATE

This is to certify that the report entitled **Seismic Performance Of Tube Structure With Regular Frame Structure** submitted by **ARYA SOMAN K** (VML19CE034) **SAHLACP**(VML19CE081) **SONU SUBHASH PV** (VML19CE093) **VARSHA K** (VML19CE101) to the APJ Abdul Kalam Technological in partial fulfilment of the requirements for the award of the Degree of Bachelor of Technology in civil engineering is a bonafide record of the project work carried out by them under our guidance and supervision. Thisreport in any form has not been submitted to any other University or Institute for any purpose.

21/6/23

Ms. Anitta Jose
(Project Guide)
Assistant Professor
Dept. of CE
Vimal Jyothi Engineering College
Chemperi

22/06/2023

Mr. Rojin P
(Project Coordinator)
Assistant Professor
Dept. of CE
Vimal Jyothi Engineering College
Chemperi

Head of the Department

Place: VJEC Chemperi

Date: 22-06-2023

Department of Civil Engineering
Date............
Chemperi

(Office Seal)

Signature Not Verified
Principal VJEC

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CERTIFICATE

This is to certify that the report entitled **"EVALUATION OF MULTIGEOGRID REINFORCED EMBANKMENT USING PLAXIS 2D"** submitted by **Ms. ANSHA KURIAN(VML19CE026), Ms. DAYA S RAM(VML19CE044), Mr. DHEERAJ MOHAN(VML19CE046), Ms. FIDA HAMEED(VML19CE050)** to the APJ Abdul Kalam University in partial fulfilment of the requirements for the award of the Degree of Bachelor of Technology in Civil Engineering is a bonafide record of the project work carried out by him under my/our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

Dr. VIBHOOSHA M P
(Project Guide)
Associate professor
Dept of CE
Vimal Jyothi engineering
Chemperi

22/6/23
Ms. HRIDYA P
(Project Coordinator)
Assistant professor
Dept of CE
Vimal Jyothi engineering college
Chemperi

Head of the department

Place : VJEC, Chemperi

Date : 26-05-2023

Department of Civil Engineering, V.J.E.C, Chemperi
Date............

Signature Not Verified
Principal.VJEC

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DEPARTMENT OF CIVIL ENGINEERING

CERTIFICATE

This is to certify that the report entitled **'Slope stability assessment and stabilization by soil nailing using GEOSTUDIO'** submitted by **Aswini P (VML19CE038), Gayathri N (VML19CE052), Haritha K V (VML19CE054), Sangeeth Krishna N V (VML19CE085), Vishnu Dineshan (VML19CE102)** to the APJ Abdul Kalam Technological University in partial fulfilment of the requirements for the award of the Degree of Bachelor of Technology in Civil Engineering is a bonafide record of the project work carried out by them under my guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

Project Guide

21/06/23

Mr. SANEESH K
Department of Civil Engineering
Vimal Jyothi Engineering College, Chemperi

Project Coordinator

21/6/23

Ms. HRIDYA
Department of Civil Engineering
Vimal Jyothi Engineering College, Chemperi

Head of the Department

Place : VJEC Chemperi
Date : 23-06-2023

VJEC, Chemperi ★ Department of Civil Engineering ★ Date

(Office Seal)

Signature Not Verif

Principal.VJE

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ENGINEERING COLLEGE
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DEPARTMENT OF CIVIL ENGINEERING VIMAL JYOTHI ENGINEERING COLLEGE, CHEMPERI

CERTIFICATE

This is to certify that the report Entitled "**Soil stabilization by powdered plastic bottles**" submitted by **Chandana K, Dayal K, Dheeraj Haridas, Dheeraj Sunith, Frinto Antony** to the APJ Abdul Kalam Technological in partial fulfilment ofthe requirements for the award of the Degree of Bachelor of Technology in civil engineering is a bonafide record of the project work carried out by under my guidance and supervision. This report inany form has not been submitted to any other University or Institute for any purpose.

Project Guide	**Project Coordinator**	**Head of the Department**
9/06/23	22/06/2023	
Ms. Saneesh K	**Mr. Rojin P**	**Dr. Biju Mathew**
Assistant Professor	Assistant Professor	Professor & Head
Department of Civil Engineering	Department of Civil Engineering	Department of Civil Engineering
Vimal Jyothi Engineering College, Chemperi, Kannur	Vimal Jyothi Engineering College, Chemperi, Kannur	Vimal Jyothi Engineering College, Chemperi, Kannur

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DEPARTMENT OF CIVIL ENGINEERING

CERTIFICATE

This is to certify that the report entitled **"STABILIZATION OF EXPANSIVE SOIL USING STEEL SLAG AND HYDRATED LIME"** submitted by **Aarya K (VML19CE001), Adarsh M (VML19CE007), Ananya Dineshan (VML19CE023), Aswathi Anil (VML19CE036)** to the APJ Abdul Kalam Technological University in partial fulfillment of the requirement for the award of the Degreeof Bachelor of Technology in CIVIL ENGINEERING is a bonafide record of the project workcarried out by them under our guidance and supervision. This report in any form has not been submitted to any University or Institute for any purpose.

FN 22/06/23

Ms. Anuragi P
(Project Guide)
Assistant Professor
Dept. of Civil Engineering
Vimal Jyothi Engineering College
Chemperi

22/6/23

Ms. Hridya P
(Project Coodinator)
Assistant Professor
Dept. of Civil Engineering
Vimal Jyothi Engineering College
Chemperi

Place: VJEC Chemperi
Date:

Head of the department

Department of Civil Engineering ★ VJEC, Chemperi
Date..........

(Office Seal)

Signature Not Verified
Principal VJEC

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VIMAL JYOTHI ENGINEERING COLLEGE, CHEMPERI

CERTIFICATE

This is to certify that the seminar report entitled **"Stabilization of Soil Using Marble Dust and PVC Waste"** submitted by "**Anandhu P V** (VML19CE022), **Nithin Jose** (VML19CE075), **Pranav E P** (VML19CE077), **Vismaya Mohan K** (VML19CE104)**"** to the APJ Abdul Kalam Technological University in partial fulfillment of the requirements for the award of Degree of Bachelor of Technology in Civil Engineering, is a bonafide record of project work carried out by them under our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

Project Guide	**Project Coordinator**	**Head of the Department**
22/06/23	22/06/2023	
Mr. Saneesh K	**Mr. Rojin P**	**Dr. Biju Mathew**
Assistant Professor	Assistant Professor	Professor & Head
Vimal Jyothi Engineering College	Vimal Jyothi Engineering College	Vimal Jyothi Engineering College
Chemperi, Kannur	Chemperi, Kannur	Chemperi, Kannur

Department of Civil Engineering
Date..............
VJEC, Chemperi