COMPARISON OF THE EFFECTIVENESS AND ECONOMY OF 850µM AND 590µM COCONUT SHELL ACTIVATED CHARCOAL PARTICLES IN WATER TREATMENT

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ABSTRACT — This study investigates the effectiveness of coconut shell activated charcoal in water treatment process using common table salt or sodium chloride (NaCl) as the activation agent and water sample sourced from Otammiri River in Imo state as the test sample while comparing the effectiveness and economy of an 850µm and 590µm particle sizes of activated carbon in the water treatment processes. To form the carbon, coconut shell was heated in open air to form the carbon (charcoal) which is then grinded into a fine state. To activate the carbon, sodium chloride was added to the fine carbon and heated in an oven to a temperature of about 600˚C. Two different particle sizes of activated carbon was produced, 850µm and 590µm. Three major parameters were analysed in accordance to WHO (World Health Organization) standard for the two different activated carbon sizes, these parameters include; Physical tests, Chemical tests, and Biological Analysis test. The results of the tests showed that while both particle size activated carbon where very effective in water treatment, the 590µm particle size of activated carbon is more effective as it yields better result within a short duration. But as regards to economy, the 850µm particle size of activated carbon is more effective as it can be easily re-used.

Index Terms — Activated carbon (Activated charcoal will be used interchangeably with activated carbon throughout this work, also written as AC), adsorption, E.Coli, Colonies, L/M → Litres/Minute, sp →Species.

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1. INTRODUCTION

Water sources and systems, globally, have been faced with the problems of pollution, both by natural causes and man-made causes. Water treatment, being a means of quality improvement remains a valuable tool for making polluted water portable. In treatment, the sources and levels of pollution tend to determine the extent of treatment facility to be adopted (Kamrin, Michael, Nancy Hayden, 1990).

Most naturally occurring water are not free from contaminants, especially surface water and atmospheric water and therefore requires one form of treatment or the other to meet acceptable quality standards for portability. Since often, suspended particles in the water constitute the pollution requiring treatment, introduction of chemical or treatment inputs that can be used to remove or separate these particles should be evaluated.

The turbidity, taste, odour, hardness, heavy metals and bacteria have placed a limit on the utility derived by the consumers of the water. Treatment to remove these therefore is pertinent for improving the quality of the water. These results to the use of chemical such as chlorine (Cl2), in water treatment but water treated chlorine can be harmful for consumption. Also, the use of chlorine in water treatment has been of great use but in excess can result to major health issues and it removes essential nutrients gotten from water such as calcium, etc.

Contamination of surface and atmospheric water, suspended particles in ground water and surface water has reduced the quality of drinking water which is why treatment is essential in order to make the water potable.

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Arbitrary choice of filtrates to be used for treatment is a bit lacking in that sand and gravel used in filtration cannot remove all contaminants.

The specific objective of this study is to check the efficiency and quality of activated carbon (charcoal) in water treatment. This objective will be pursued by, evaluation of the ability of activated carbon in removing some physical contaminants in water; ascertaining the efficiency of the activated charcoal in removing some chemical contaminants in water; evaluating the ability of activated charcoal in adsorbing microbial pathogens in water; and studying the adsorption efficiency of two different activated charcoal of different particle sizes (prepared from coconut shells and activated with sodium chloride, common salt) in the removal of pollutants in water.

2. RESEARCH METHOD

2.1 Materials and Methods

Materials used during this experiment include the following: 25 pieces of 250mL and 3 pieces of 1000mL of glass bakers; Sodium chloride NaCl (common salt); Activated carbon (prepared from coconut shell and using sodium chloride as activating agent); pH and Conductivity Meter; turbidity meter; Colour meter; Distilled water; Domestic mortar and pistol; Stop watch; Funnel; Volumetric Flask; Sieve; Filter; Measuring Cylinder.

The 20 litres (or 4 and half gallons) of raw water sample was collected from Otammiri River. The filtrate used during this project is the carbonized coconut shells which will be activated with sodium chloride also known as common salt. The coconut shells were obtained from a farm in Obazu Mbieri Mbaitoli in Imo state, Nigeria.

2.1.1 Experimental Design

A completely Randomized Design was used for this experiment. Granular and pulverized carbonized coconut shell were concentrated and activated with sodium chloride (common salt). For the preparation of the activated carbon, a completely new and innovative method was adopted. This innovation has two parts;

1. Making good quality Coconut charcoal by improving the production process:

For this an iron pot was used to burn the coconut shell. The iron pot was used because when put under a very hot temperature it doesn't melt easily and it has a very high tendency of supporting the carbonization process by speeding up the heating and keeping t tightly covered. The pot was then put in an electric muffle furnace and set to a temperature of 600°C for 2 hours. But this was done after the coconut shells were broken into small pieces, washed thoroughly to remove particles and dirt on it and sun dried. This was done repeatedly till all the shells were carbonized. Now Water is poured to cool the charcoal. It is dried to get good quality coconut charcoal. The model can take about 8 coconut shells. But bigger chambers of can be fabricated to hold about 20 to 50 shells at a time.

2. Making of activated carbon from coconut shell charcoal:

The charcoal produced in the method given earlier is mixed with sodium chloride (table salt). The Sodium chloride is to be measured using weighing balance of 20g was mixed with a 10m of 1000mL distilled water respectively to form a paste. The paste is then dissolved into the remaining distilled water of 1000ml and stirred for 5min in a magnetic stirrer with a speed of 100rpm. This solution will be mixed with the carbon with iodine value up to 750.

The Activated carbon is then grinded to two particle sizes (850μm and 590μm), this was done so as to increase its surface area and to improve its adsorptive capacity.

2.2 Tests Conducted

A total of 22 tests was carried out on the water sample to ascertain the suitability and portability of the treated water in accordance to WHO standard. These tests can be grouped into Physical, Chemical, and Biological test. The tests to be conducted are summarized in Table 2.1 below while some of the test results as expected for a suitable and portable water according to WHO standards are summarized in Table 2.2 and Table 2.3 below;

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Table 2.1: Parameters Analysed

PHYSICAL TEST	CHEMICAL TEST	BIOLOGICAL TEST
Conductivity	PH	Coliform: Other coliform -E. coli
Turbidity	Dissolved oxygen	Faecal streptococci
Total solids	Heavy metals (Cu, Zn, and Fe)	Salmonella
Total suspended solids	Nitrate	Vibrio
Total dissolved solids	Phosphate	Clostridia
	Sulphate	Yeast/moulds/parasites
	Biochemical oxygen demand (BOD)	Planktons
	Chemical oxygen demand (COD)	Total plate counts
	Chloride	

Table 2.2: Bacteriological Analysis

Parameter	Recommended raw water quality	Drinking water standards
	Acceptable value (mg/litre, unless otherwise stated)	**Maximum acceptable value (mg/litre, unless otherwise stated)**
Total coliform	5000MPN/100ml	0 in 100 ml
E.coli	5000MPN/100ml	0 in 100 ml
Coliform Bacteria	___	Absent

Table 2.3: Physical and Chemical Analysis

Parameter	Unit	Test Remarks	Requirement	Methods
Colour	Pt. Co-scale	3	15	Colorimetric
pH	Pt. Co scale	6.50	6.5-8.5	Electrometric
Turbidity	NTU	1	5	Turbidity meter
Copper	Mg/l	Below 0.3	1.0	AAS
Zinc	Mg/l	0.047	5	AAS
Iron Total	Mg/l	Below 0.4	0.3	AAS

**NTU= Nephelometric Turbidity Unit, *AAS= Atomic Absorption Spectrophotometer*

2.2.1 Filtration Procedure

The filtration bed was set up and filtration was carried out in accordance to WHO standard. Also, results were completely analysed as specified by WHO.

3. RESULTS AND DATA ANALYSIS

3.1 Data Presentation

Two samples of filtered water were obtained by filtering the raw water with two different particle size of activated carbon. Sample 1 was obtained by filtering the raw water through the 850μm particle size of activated carbon while sample 2 was obtained by doing same through a 590μm particle size activated carbon. For each sample, 5 different sub-samples namely; Control, Sample A, Sample B, Sample C and Sample D, were obtained by collecting the filtered water at specific flow rates. The flow rates are; Sample A (At flow rate of 1L/15Mins), Sample B (At flow rate of 1L/30Mins), Sample C (At flow rate of 1L/45Mins), Sample D (At flow rate of 1L/60Mins) and the Control was the raw water sample before filtration (that is, 0L/Min).

1-litre of water being filtered was collected at 15minute intervals for the two different activated carbon particle size and tested. The various graphs of each physical and chemical parameter tested are plotted against the various collection flow rates for the two activated carbon particle sizes.

It should be noted, for the graphs below;

Sample 1 = water filtered through 850μm AC particle size,

Sample 2 = water filtered through 590μm AC particle size. Also, on the flow rate axis;

1= Raw water sample collected before filtration,

2 = water sample A collected after 15mins,

3 = water sample B collected after 30mins,

4 = water sample C collected after 45mins and

5 = water sample D collected after 60mins

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3.1.1 Physical Tests Result:

Physical tests are summarized in Fig 1-5 below;

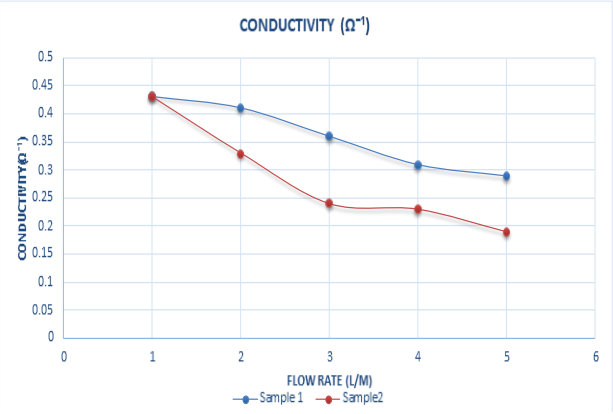

Fig 1: Change in Conductivity at Different Flow Rates

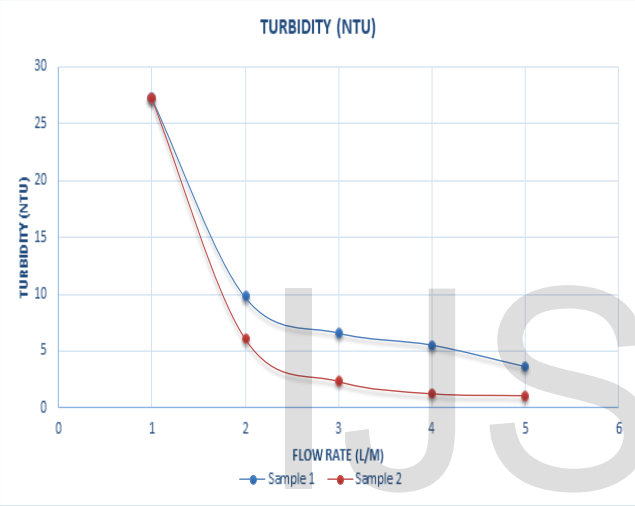

Fig 2: Change in Level of Turbidity

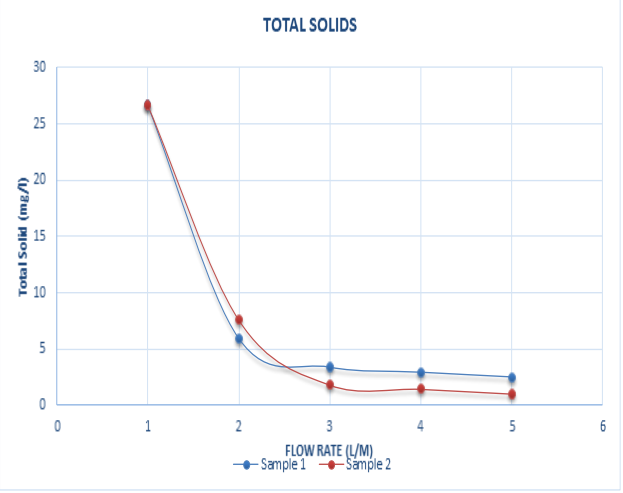

Fig 3: Change in Level of Total Solids

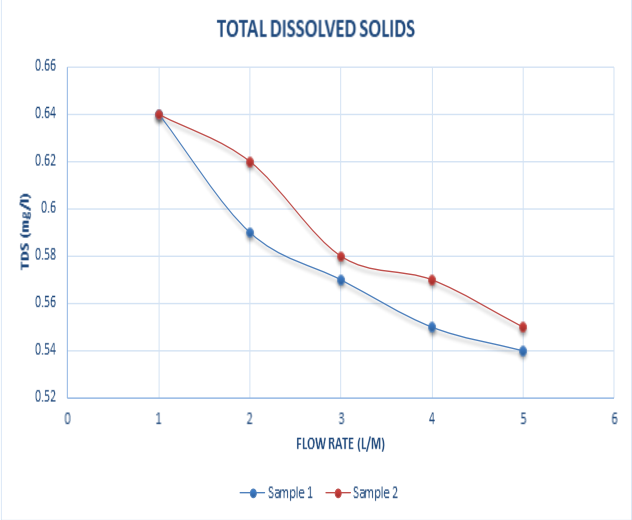

Fig 4: Change in Level of Total Dissolved Solids

Fig 5: Change in Level of Total Suspended Solids

3.1.2 Chemical Tests Result:

Physical tests are summarized in Fig 6-17 below;

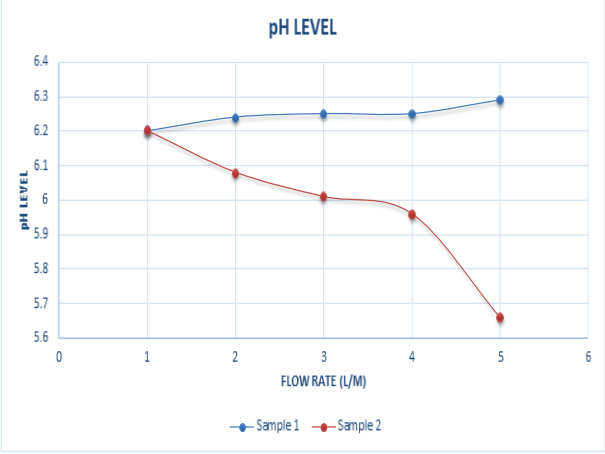

Fig 6: Change in pH Level

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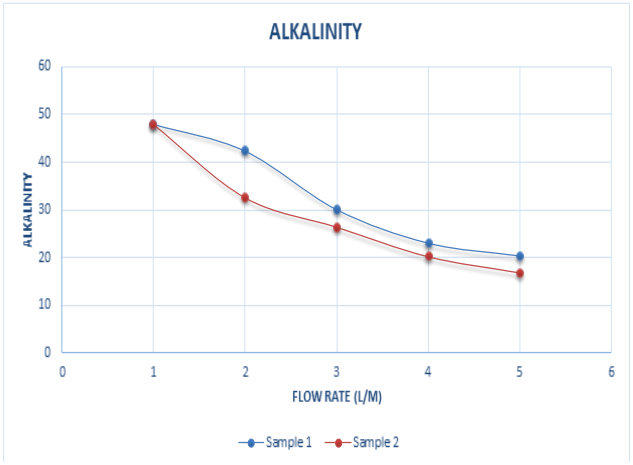

Fig 7: Change in Level of Alkalinity

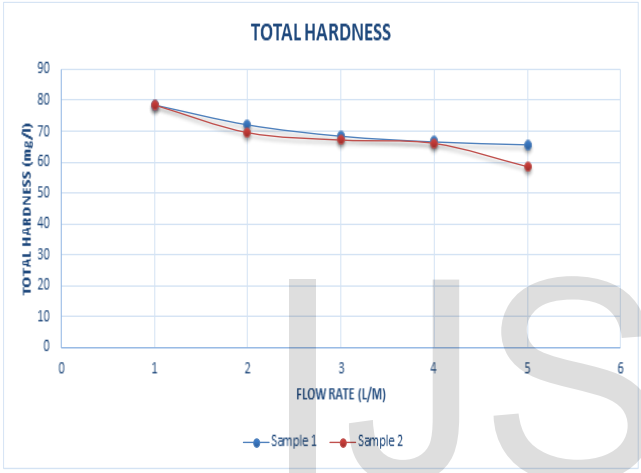

Fig 8: Change in Level of Total Hardness

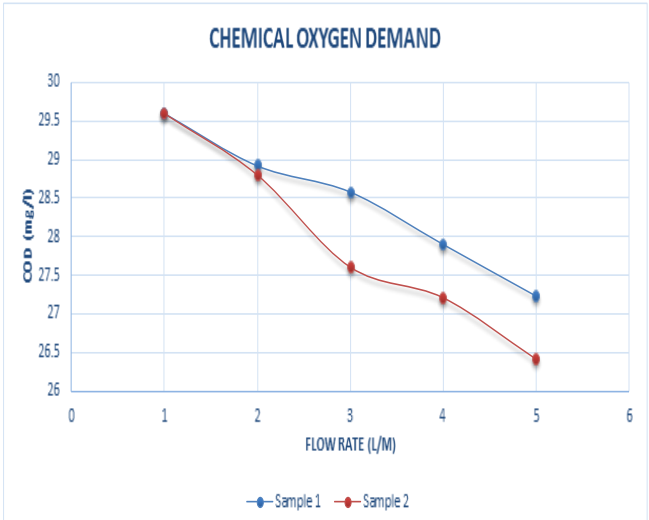

Fig 9: Change in Level of Chemical Oxygen Demand

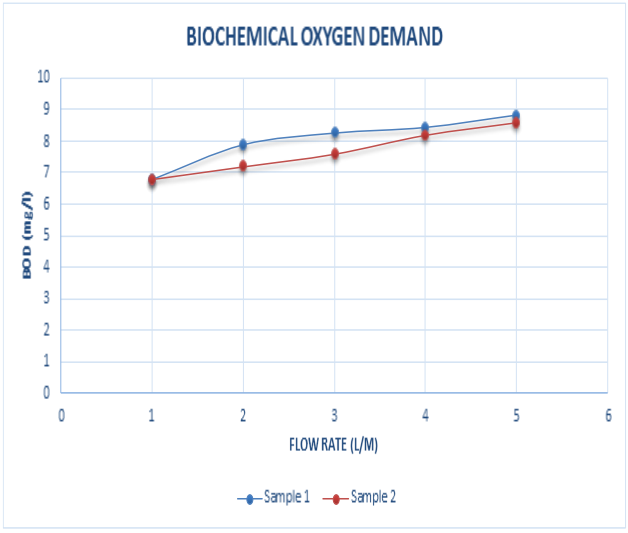

Fig 10: Change in Level of Bio- Chemical Oxygen Demand

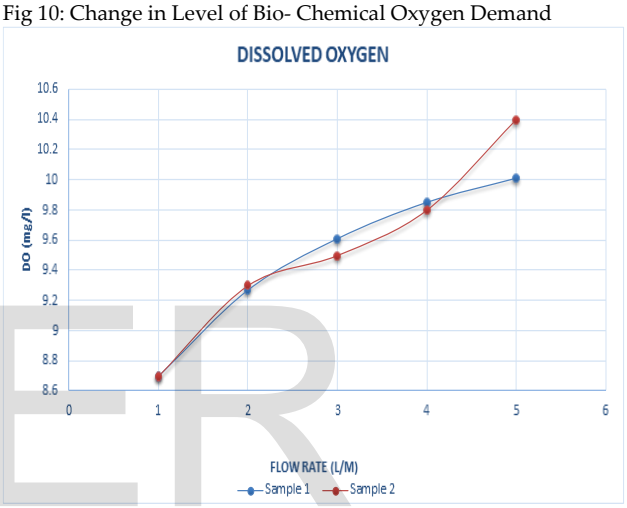

Fig 11: Change in Level of Dissolved Oxygen

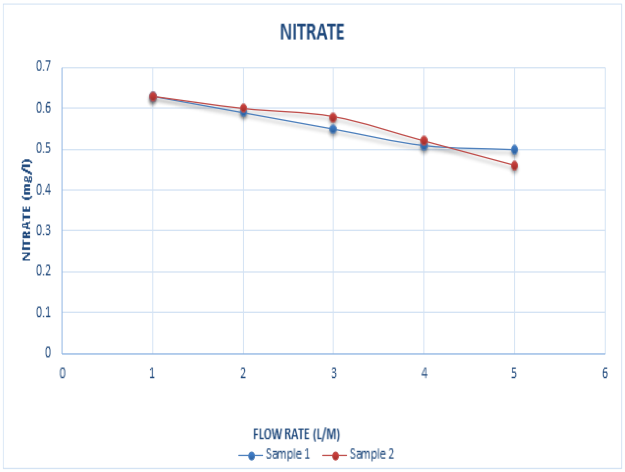

Fig 12: Change in Level of Nitrate

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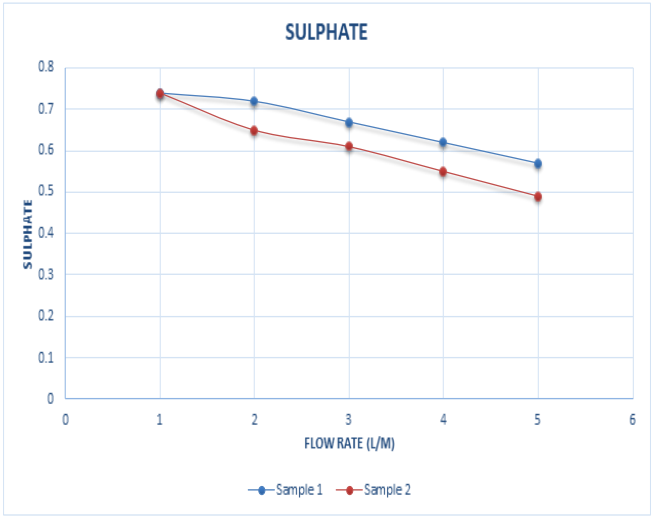

Fig 13: Change in Level of Sulphate

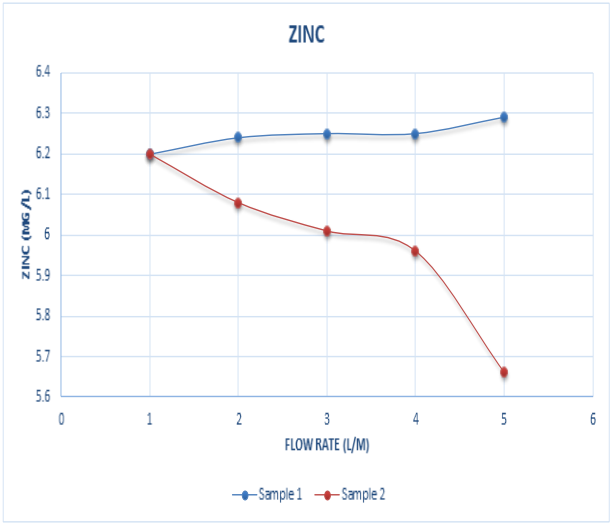

Fig 16: Change in Level of Zinc

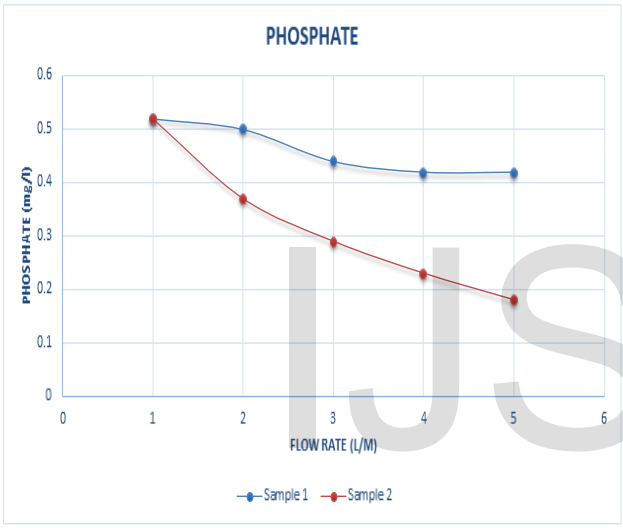

Fig 14: Change in Level of Phosphate

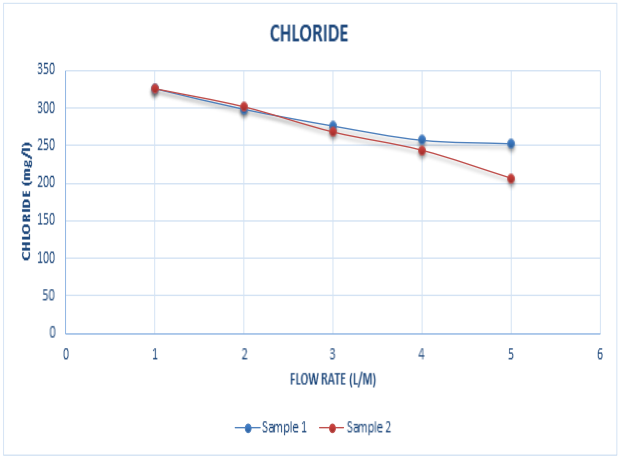

Fig 15: Change in Level of Chloride

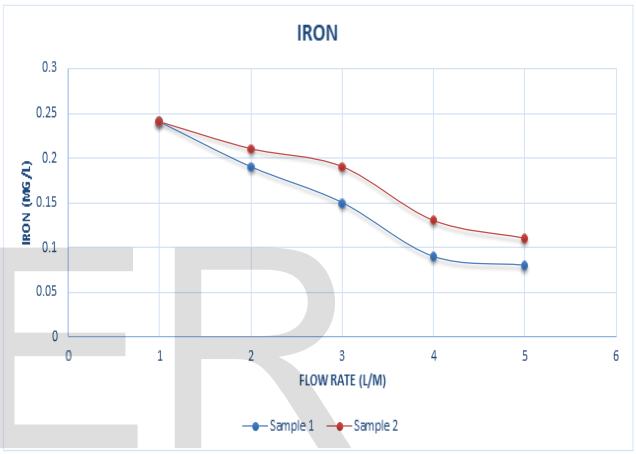

Fig 17: Change in Level of Iron

3.1.3: Biological Tests:

For the first sample treated activated carbon of particle size 850µm

Table 4: Control Sample

MICROBIAL GROUP	PLATE READING	UNIT (CFU/ML)
PATHOGENS		
Coliform: Other coliform **E. coli**	Nil 35 colonies	Nil 35 colonies
Faecal streptococci sp	Nil	Nil
Salmonella sp	Nil	Nil
Vibrio sp	Nil	Nil
Clostridia sp	Nil	Nil
Yeast/molds/parasites	Nil	Nil
Plankton	Nil	Nil
TOTAL-PLATE COUNTS	**50 colonies**	**5.0 x10²**

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Table 5: Sample A

MICROBIAL GROUP	PLATE READING	UNIT (CFU/ML)
PATHOGENS		
Coliform: Other coliform E.coli	Nil 14 colonies	Nil 14 colonies
Faecal streptococci sp	Nil	Nil
Salmonella & Vibrio sp	Nil	Nil
Clostridia sp	Nil	Nil
Yeast /molds/parasites	Nil	Nil
Plankton	Nil	Nil
TOTAL-PLATE COUNTS	25 colonies	2.5

Table 6: Sample B

MICROBIAL GROUP	PLATE READING	UNIT (CFU/ML)
PATHOGENS		
Coliform: Other coliform E.coli	Nil 12 colonies	Nil 12 colonies
Faecal streptococci sp	Nil	Nil
Salmonella & Vibrio sp	Nil	Nil
Clostridia sp	Nil	Nil
Yeast/molds/parasites	Nil	Nil
Plankton	Nil	Nil
TOTAL-PLATE COUNTS	45 colonies	4.5×10^2

Table 7: Sample C

MICROBIAL GROUP	PLATE READING	UNIT (CFU/ML)
PATHOGENS		
Coliform: Other coliform E.coli	Nil 10 colonies	Nil 10 colonies
Faecal streptococci sp	Nil	Nil
Salmonella & Vibrio sp	Nil	Nil
Clostridia sp	Nil	Nil
Yeast/molds/parasites	Nil	Nil
Plankton	Nil	Nil
TOTAL-PLATE COUNTS	30 colonies	3.0×10^2

Table 8: Sample D

MICROBIAL GROUP	PLATE READING	UNIT (CFU/ML)
PATHOGENS		
Coliform: Other coliform E.coli	Nil 7 colonies	Nil 7 colonies
Faecal streptococci sp	Nil	Nil
Salmonella & Vibrio sp	Nil	Nil
Clostridia sp	Nil	Nil
Yeast/molds/parasites	Nil	Nil
Plankton	Nil	Nil
TOTAL-PLATE COUNTS	28 colonies	2.8×10^2

For the second sample treated with activated carbon of particle size of 590μm;

Table 9: Sample A

MICROBIAL GROUP	PLATE READING	UNIT (CFU/ML)
PATHOGENS		
Coliform: Other coliform E.coli	Nil 11 colonies	Nil 11 colonies
Faecal streptococci sp	Nil	Nil
Salmonella & Vibrio sp	Nil	Nil
Clostridia sp	Nil	Nil
Yeast/molds/parasites	Nil	Nil
Plankton	Nil	Nil
TOTAL-PLATE COUNTS	22 colonies	2.2×10^2

Table 10: Sample B

MICROBIAL GROUP	PLATE READING	UNIT (CFU/ML)
PATHOGENS		
Coliform: Other coliform E.coli	Nil 3 colonies	Nil 3 colonies
Faecal streptococci sp	Nil	Nil
Salmonella & Vibrio sp	Nil	Nil
Clostridia sp	Nil	Nil
Yeast/molds/parasites	Nil	Nil
Plankton	Nil	Nil
TOTAL-PLATE COUNTS	12 colonies	1.2×10^2

Table 11: Sample C

MICROBIAL GROUP	PLATE READING	UNIT (CFU/ML)
PATHOGENS		
Coliform: Other coliform E.coli	Nil 15 colonies	Nil 15 colonies
Faecal streptococci sp	Nil	Nil
Salmonella & Vibrio sp	Nil	Nil
Clostridia sp	Nil	Nil
Yeast/molds/parasites	Nil	Nil
Plankton	Nil	Nil
TOTAL-PLATE COUNTS	8 colonies	8.0×10^2

Table 12: Sample D

MICROBIAL GROUP	PLATE READING	UNIT (CFU/ML)
PATHOGENS		
Coliform: Other coliform E.coli	Nil 7 colonies	Nil 7 colonies
Faecal streptococci sp	Nil	Nil
Salmonella & Vibrio sp	Nil	Nil
Clostridia sp	Nil	Nil
Yeast/molds/parasites	Nil	Nil
Plankton	Nil	Nil
TOTAL-PLATE COUNTS	6 colonies	6.0×10^2

3.2. DISCUSSION OF RESULTS

3.2.1. Discussion on the Physical Test

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Turbidity: in sample 1, activated carbon of 850μm size, the water became clear at sample D (flow rate of 1L/60min) with turbidity of 3.64NTU, while the second sample (590μm AC size) became clear at sample B (flow rate of 1L/30mins) with turbidity of 2.34NTU as shown in FIG 2 above. Also, from FIG 1 above, sample 2 has a lower conductivity compared to sample 1. This clearly shows that while both particle sizes of the activated carbon were effective in clearing the water (WHO Standard for turbidity in 5.0NTU), the smaller AC particle size was more effective, reducing the turbidity to a minimum at a very short time interval.

Total solid, total dissolved solids and total suspended solids: these gave positive results to how effective the activated carbon of both particle sizes responded to the removal of these contaminants as from FIG 3, FIG 4 and FIG 5 above. But it can be clearly seen that the smaller particle size activated carbon was more effective.

3.2.2. Discussion on the Chemical Test

The Ph is an indicator of relative acidity or alkalinity of water. Values of 9.5 and above indicate high alkalinity while values of 3 and below indicates high acidity level. Both samples were appropriate and fell between the given standard of 5.5 - 8.5 for all flow rates as seen in FIG 6 and FIG 7.

The heavy metals (Fe and Zn) were both impressive with their outcomes, copper was not found in the raw water that is why no result was given. Iron and Zinc, from FIG 16 and FIG 17, both fell drastically below WHO standard after the treatment for sample A (1L/15min) for both samples which showed a huge progress on how activated carbon is at removing certain heavy metals.

Nitrates, phosphate, sulphate, and chloride also yielded wonderful result as from FIG 12, 14, 13 and 15 respectively, and they all fell below standards except for chloride treated with activated particle size of 850μm (FIG 15) which will eventually yield a better result if left for longer time period. for sample D, the level of chloride in the water after treatment was 3.49mg/l out of 253.49mg/l while its standard is 250.0mg/l. The BOD, COD and DO gave reasonable results as seen from FIG 10, 11 and 9 respectively.

3.2.3. Discussion on the Biological Test

Bacteriological tests show the presence of bacteria, characteristic of faecal pollution, coliform (E.coli), pathogens (salmonella, vibrio, clostridia), parasites, planktons, etc. which improved with satisfactory results after treatment (Tables 4 - 12 above). The raw water which contained faecal coliform was completely removed and the rest of also produced satisfactory result according WHO allowable limit for potable drinking water which stated that the following micro-organisms listed above should be below 100 colonies but in these test the total plate count for the first sample was 25colonies for sample A, 45 colonies for sample B, 30 colonies for sample C, and 28colonies for sample D.

3.3. CHARACTERIZATION OF ACTIVATED CARBON

Adsorptive characteristics: Iodine number was determined to access the absorptive capacity of prepared activated carbon. Iodine adsorption is easy and commonly used methods to characterize activated carbon performance. Iodine is a small sized molecule, so it indicates the capacity of carbon to adsorb smaller molecules. However, the higher the iodine number the better its adsorptive capacitance. For the first activated carbon its iodine number is 510mg/gm while that of the second is 764mg/gm.

Table 13: Compilation of characteristics of the two different activated carbon

CHARACTERISTICS	FIRST ACTIVATED CARBON	SECOND ACTIVATED CARBON
Particle sizes **Mesh** **Inch**	850μm (0.850mm) No. 20 0.0331	590μm (0.590mm) No.30 0.0234
Bulk density g/ml	0.731	0.743
Conductivity (Ω^{-1})	0.01	0.02
PH	7.08	7.31
Ash content %	2.05	2.21

4. CONCLUSION AND RECOMMENDATION

4.1 CONCLUSION

Activated carbon adsorption is an effective means for reducing organic chemicals, chlorine, and unpleasant tastes and odors in water, (Guo J and Lua A.C. 2001).

This treatment can produce water of more desirable quality than that from some public or private supplies. Units ranging from simple, manually operated devices to complex, automatic ones are designed to ensure the reduction of specific contaminants. The 590μm particle

size activated carbon is more effective as it yields better result within a short duration. But as regards to economy, the 850μm particle size activated carbon is advised as it can be easily re-used.

The effect of activating agents on the properties of activated carbon prepared from coconut shell by chemical activation has been investigated. Activating agents had no significant effect on the nature of surface functional group. Activated carbon impregnated with sodium chloride showed well developed pores structure. Iodine Number adsorption also indicates that sodium chloride is the best activating agent among the various activating agents tested. Hence this study shows that coconut shell can be used as a source of lignocellulosic material for the preparation of low cost, high surface area activated carbon with well-developed porosity using NaCl as an activating agent.

4.2. RECOMMENDATION

Based on the findings of this research work, the use of chemically activated carbon is very much effective in water treatment processes. The particle sizes in this research also showed that the smaller/finer the particle size of the activated carbon the better it is at giving the water a better quality within a short time frame, but using a smaller particle sized activated carbon would require changing the filter after use every 2-3 weeks, the cost of using smaller particle sized activated carbon will then be high. Lager particle size filters are advisable to use in water treatment because it can easily be reactivated and re-used.

In terms of speed, the 590μm particle size activated carbon was quicker in the water treatment process and more effective overall. To obtain a similar purity with the 850μm particle size activated carbon, the water will have to be treated more than once.

Overall the 850μm particle sized activated carbon is recommended due to its relative cheap cost on a mass scale and ability to provide relatively clean water for a large community at a reasonable cost.

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