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Design of Locally Produced Activated Carbon Filter from Agricultural Waste for Water Purification

Y. Danyuo *, E. K. Arthur, S. T. Azeko, J. D. Obayemi and I. M. Asuo
Department of Materials Science and Engineering,
African University of Science and Technology,
Federal Capital Territory, Abuja-Nigeria.

Y. Danyuo *, S. T. Azeko
Nigerian Turkish Nile University,
Federal Capital Territory, Abuja- Nigeria.

J. D. Obayemi
Department of Materials Science and Engineering,
Kwara State University, Malete, Ilorin-Nigeria.

***Abstract*-This paper presents basic design and fabrication of activated carbon filters from agricultural wastes (coconut and palm kernel shells) for water purification in the Northern Region of Ghana. The content of the activated carbon (AC) produced were between 80 and 90 vol. %, depending on the type of the agricultural waste used in water purification. Adsorption and turbidity tests were carried out. The test results indicated that, AC with favorable physicochemical properties can be produced locally from agricultural waste. The volume percentage of impurity removed was also evaluated to be ~97 ± 2 vol. %. The superficial water flow velocity through the porous AC was found to be 1.62 m/s. Also, the volumetric flow rate was determined to be 0.056 m^3/s. The filter is capable of producing 0.02 m^3 of water in 2 hours. Also, the work show that, the contact time between water and the AC increases the amount of impurities removed. A paired sample T-test was used to analyse the flow rate results for both AC produced. The results obtained are then discussed for the production of locally AC filters for water purification.**

Keywords— activated carbon; water filter; adsorption; turbidity; impurities; statistical analysis.

I. INTRODUCTION

Water is essential for human wellbeing and the environment. Beyond meeting basic human needs, water supply and sanitation services, as well as water as a resource, are critical to sustainable development. In Ghana, 58% of the populations live in rural areas. Out of these communities, 66% of the population lack access to clean and safe drinking water [1]. In the Northern Region of Ghana, people lack access to portable water. About 40% of the populace in the region obtains their source of drinking water from boreholes, dams and streams [2]. These sources of drinking water are untreated and exposed to many contaminations. As a result, they have incidence of water-borne diseases (diarrhea, hepatitis A, typhoid, cholera and guinea worm) which are high in the Northern Region. Guinea worm has been eradicated in almost all parts in the world. However, Ghana is still the second highest rated country with cases of guinea worm in the world, next to Sudan with 501 new cases reported in 2008 [3,4]. Drinking water from contaminated sources including inadequate sanitation and hygiene practices are some of the contributing factors to waterborne diseases [5]. In water related diseases, guinea worm and diarrhea are the predominant, with diarrhea constituting one third of the reported cases in health centers across the country [5]. A total number of 113,786 cases of diarrhea among children under five years with 354 deaths cases were reported in 2011 [6]. This problem is intensified due to lack of safe sanitation and poor water quality in poor countries [7-9].

Sawla-Tuna-Kalba District is located in the western part of the Northern Region, between latitudes 8° 401 and 9° 401 North and longitudes 1°501 and 2° 451 West. The population of Sawla-Tuna-Kalba according to the Ministry of Health population and housing census in 2000 was estimated to be 84,664 with a population density increasing from 8 persons per square Km in 1984 to 14 persons per square km in 2000 [6]. Eighty five percent (85%) of the total population in the district lived in rural areas, whiles fifteen percent (15%) lived in the urban areas [10]. Recent survey conducted indicates that, a community such as Dakompilayiri owned just a single borehole to provide portable drinking water for the entire community. Unfortunately, this borehole breaks down consistently for almost every season due to excessive human pressure. In such situations, people were left with no choice than to depend on stream/dugout (Fig.1a) and dam (Fig.1b) water for their daily use.

Fig. 1a: Hand Dugout Water Supply at Bupila-Stream (near Dakompilayir) During the Dry Season (Nov. – March, 2014).

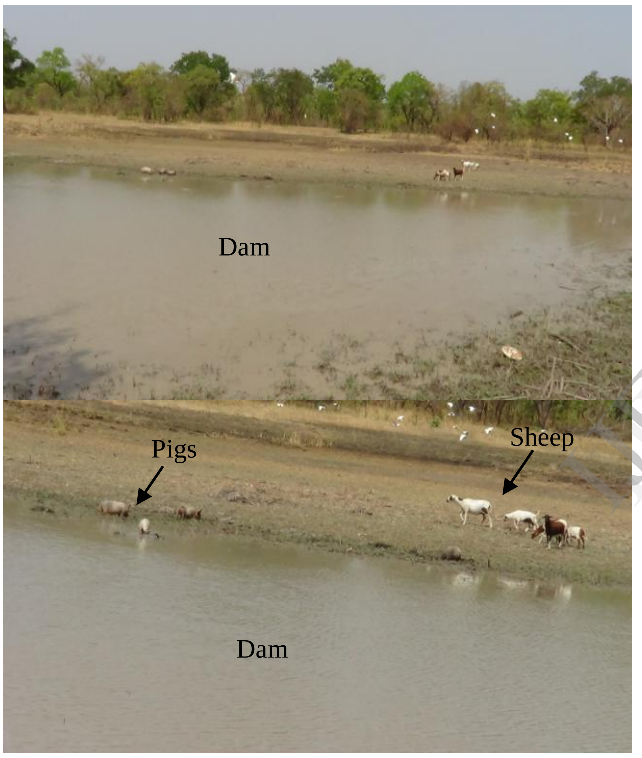

Fig. 1b: Dakompilayir Dam During the Dry Season (Nov. – March, 2014).

In some cases these water bodies are polluted by animals/human activities including: farming along the water bodies and sometimes polluted by illegal fishing from neighboring towns like Tuna. This makes women to spend hours each day at local dugouts trying to collect water for their families. There is an urgent need for portable water supply for the people of Dakompilayiri (originally known as Bayelteng) community.

This paper presents basic design and fabrication of activated carbon filter from agricultural waste (coconut and palm kernel shells) for water purification in the Northern region of Ghana.

A. Activated Carbon Water Filtration

Carbon is a substance capable of absorbing impurities in polluted/contaminated water [11]. Activated Carbon (AC) is a general name given to a group of absorbing substances of crystalline form. AC has a large internal pore structures that make the carbon more absorbent [12,13]. ACs has practically been used in domestic, commercial and industrial sectors. For instance, AC has been extensively used in the food industry; for de-colorization, deodorization, taste removal, removal of heavy metals and organic contaminants from liquids [14]. AC is also used in water de-chlorination and processing of foods, and for the adsorption of harmful chemicals and drugs [14]. Carbon is described as one of the magnificent elements which have revolutionized material science in recent years [15-18]. From carbon, we can obtain the best porous absorber (activated carbon) with excellent properties for large spectrum of industrial applications. The raw materials for the production of AC are those with high carbon but low inorganic contents (e.g. wood, lignite, peat and coal) [19]. AC is produced from organic based materials such as coconut shells, palm-kernel shells, wood chips, sawdust, corn cobs, seeds, animal bone and among others [20,21]. The raw material is carbonized to obtain the char or carbonaceous material, which is then activated in an oxygen free environment at temperature of about 700°C to yield a highly porous product [22]. AC filtration is mostly effective in removing organic contaminants and chlorine from water [23]. It can also reduce the quality of lead, dissolved radon, and harmless taste and odor causing compounds [11,23].

Basically, organic substances are composed of two basic elements namely carbon and hydrogen [24]. These chemicals are often responsible for taste, odor, color problem [11]. AC filtration can be used to improve the aesthetic nature of water [11]. It has the ability to remove chlorine, some metals and radon [11]. This method of filtration is recognized by the Water Quality Association as an acceptable method to maintain certain drinking water contaminants within the limits of the Environmental Protection Agency National Drinking Water Standards [25].

There has been a great demand for AC in the Ghanaian community [26]. From the period of (1992-1996) Ghana imported about 2,900,000 kg of AC valued at nearly $ 266,000 (US) [27]. Ghana has a high potential of organic-based raw materials for the production of AC [26]. There is, however, limited production of AC in the country [28]. The demands of AC were increased over the years and the market growth was estimated at 4.6 % per year [28]. The strong market position held by AC relates to their unique properties and low cost compared with that of possible competitive inorganic adsorbent like zeolites. This demand can be satisfied by considering the large number of raw material available for the production of AC in Ghana to meet the demand of the country and other parts of Africa.

In this work, agricultural wastes (coconut and palm kernel shells) were used to produce AC due to high carbon and low inorganic content as well as their availability and low cost. In Ghana, the major production areas of these waste materials are located in large coconut/palm plantation farm lands at Akame (in the Volta Region), Asuansi, Benso, Ayiem, Axim, Salma and Akosuno (in the Western Region), Kade (in the Eastern Region) and Juziben (in the Ashanti Region) [29]. Ghana produces about 397,502 metric ton of oil palm with a projected cropped area of 2,000,000 metric ton [29], and their by-products could serve as raw materials for the production of AC.

The current work focuses on the design and fabrication of AC filter using coconut and palm kernel shells for water purification. In this study, design/setup was explored for water purification using AC filters from coconut/palm kernel shells. The results obtained from this work are then explored for the fabrication of locally AC filters for water purification.

II. MATERIALS AND METHODS

A. Materials Selection for Activated Carbon

The organic materials used as the raw materials for the production of AC were rich in carbon, fused upon carbonization. The following factors were considered during the selection of raw materials for the preparation of porous carbon (AC). These were: high carbon content, low inorganic content (i.e. low ash), high density and sufficient volatile content, the stability of supply in the country, inexpensive materials and availability. Based on the above factors, coconut and palm kernel shells were considered to be the appropriate choice for the production of the AC.

B. Production of Activated Carbon

Raw materials were prepared from coconut and palm kernel shells (10 kg each). These were then carbonized in two separate pits at temperature of 800°C in the absence of oxygen to form a char. Fig. 2 is a flow chart that shows a summary of the experimental procedure during the production of activated carbon (AC). After carbonization, two standard activation methods were used to develop the pore structures and surface area. After the initial treatment and pelletizing, gas activation was first employed to carbonize at 400-500ºC to eliminate the bulk of the volatile matter, and then partial gasification was achieved at 800-1000°C to develop the porosity and surface area. A mild oxidizing gas (steam), or flue gas, was used in the gasification step. The intrinsic surface reaction rate was much slower than the pore diffusion rate, thereby ensuring a uniform development of pores throughout the pellet. Thus during the treatment process, certain parts of the raw material transforms into gas and leave pores behind.

C. Design Principles

The designed filter contains granular AC loaded in an inner plastic container (carbon cartridge) at the point of entering (Fig. 3). The cross-sectional area of the filter cartridge decreases from top to bottom causing the pressure to increase at the bottom of the filter. A reservoir is mounted on the collector for an easy access to water.

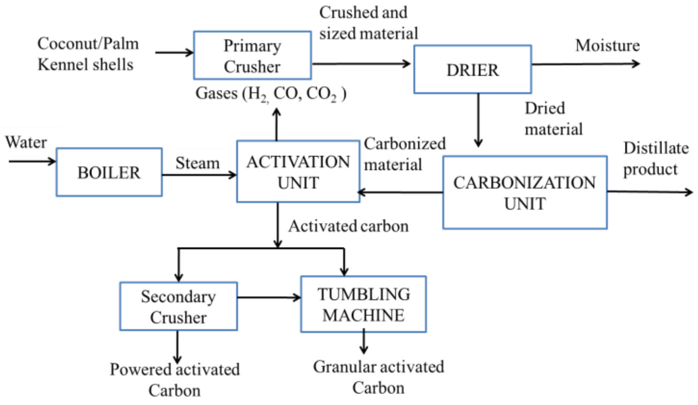

Fig. 2: Flow Diagram Showing the Steps in the Production of AC.

As water from the reservoir flows through the AC-cartridge, the rate of water permeability through the granular AC increases. The design includes a tap that regulate the water from the reservoir at the point of entry and then a second tap is located at the bottom of the collector to aid in the collection of treated water.

D. Turbidity Test

Turbidity is a very important parameter used to assess water quality [30]. Turbidity test were the key indicator used to assess the suitability of the ACs produced from both coconut and palm kernel shells in the water purification. Water turbidity measurement was carried out on-site. Turbidity is more accurately measured on-site as it can change rapidly during transport or storage [31]. Turbidity tubes were designed and build from a transparent plastic tube according to a guide [30] (Fig. 4). It was then tested and used in this research work. One of the turbidity tubes was filled with 50 mL of bottled water, while another 50 mL turbidity tube was filled to the line with sample waters collected from the dam and dugout. Cloudiness was compared by observing the fuzziness of the black dot at the bottom of the tube in a light. By the standard, a drinking water should have a turbidity of ≤ 5 Nephelometric Turbidity Units (NTU) [32]. This is because turbidity becomes visible at approximately 5 NTU, and water with any visible turbidity may be rejected in favor of a clearer, possibly more contaminated source [30].

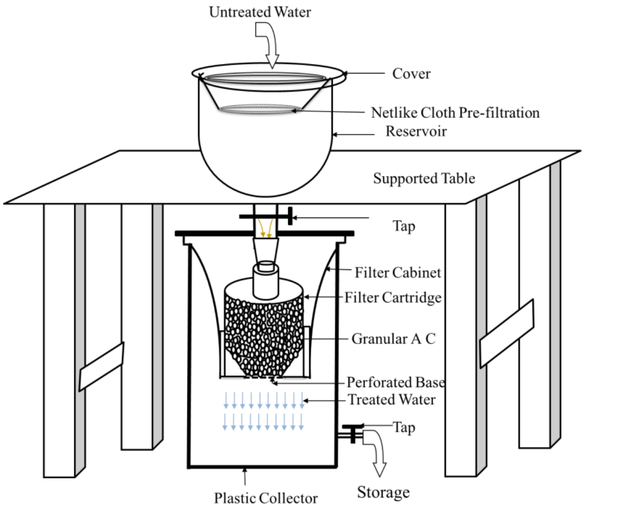

Fig.3 Schematic of the Activated Carbon filtration System.

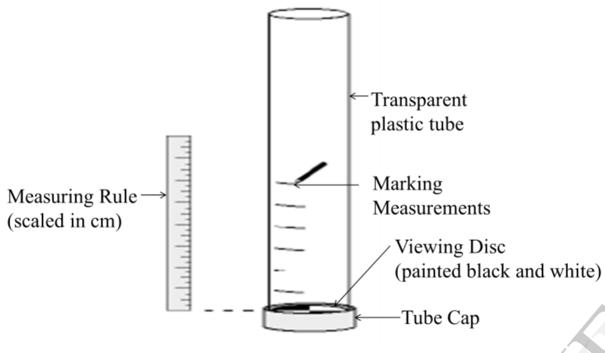

Fig. 4 Schematic of a Constructed Turbidity Tube

60 mL standard turbidity reagent (0534A11, Thomas Scientific, Swedesboro, NJ, USA) was vigorously shaken, whiles 0.5 mL of the reagent was added (which was marked by a line on the pipette) to the tube of clear water. The turbidity was compared again by looking down into the water in each tube at the black dot. 0.5 mL increments of the turbidity reagent were continuously added until both tubes appear equally cloudy. Jackson Turbidity Units of the sample were computed. Each of the 0.5 mL of Turbidity Reagent added to the clear water equals 5 Jackson Turbidity Units (0.5 mL = 5 JTUs). The results were recorded in centimeters.

The relationship between the depth (D) of the viewing disc and the turbidity was related by [30]:

$$Depth\ (cm) = 244.13x(T_{NTU})^{-0.662} \qquad (1)$$

where T_{NTU} is the Turbidity in NTU. The waste liquid was then disposed by pouring it down the drain.

E. Adsorption Measurement

Good indications of an AC filter to remove organic compounds were determined from iodine number. This measurement relates the amount of iodine (in mg) adsorbed by 1g of AC filtration under a set conditions [23].

In this study, similar measurements were obtained from AC filters loaded with the two ACs produced. In the study, 0.1 g of AC was placed in a 250 cm^3 dry Erlenmeyer flask and fully wetted by 10 cm^3 by diluted HCl (5% by weight). Then 100 cm^3 of iodine solution (0.1 mol/L) was poured into the flask and the content was vigorously shaken for 30 s. The samples were filtered and then 50 cm^3 was titrated with 0.01 mol/L sodium thiosulfate. For the amount of methylene blue, 1.0 g of AC was added into a 100 cm^3 solution containing 0.5 g/L methylene blue and has been stirred for 5 days at 30ºC. The aqueous phase concentration of methylene blue was analyzed prior to the filtration. An adsorption test was carried out to characterize the adsorption ability of the produced AC in the waste water treatment.

F. Adsorption Isotherm

Langmuir isotherm is a simple application of the mass action law leading to the thermodynamic equilibrium constant [33]. This links the concentration of free sites on the adsorbent with the adsorbate concentration in the solution and the concentration of complex sites at the adsorbent surface [33]. On the other hand, the simple and empirical Freundlich equation is the most important and commonly used isotherm equation for describing multilayer adsorption [34]. It has no saturated adsorption value and it is widely applied in physical and chemical adsorptions, as well as in solution adsorption. The liquid phase isotherms are generally interpreted using the Freundlich equation. The empirical Freundlich adsorption isotherm was used to relate the amount of impurity in the solution phase to the impurities in the adsorbed phase was given as [35].

$$x/m = kc^{1/n} \qquad (2)$$

where x is the amount of impurity adsorbed at equilibrium, m is the weight of carbon used and c is the concentration of the impurities remaining in the water, x/m is the concentration of the adsorbed state (i.e. the amount of impurity adsorbed per unit weight of carbon used (mg chemical/g AC). k is the adsorption capacity at unit concentration $(mg/g)(L/mg)^{0.5}$. k is obtained from the intercept of a linear plot of log (x/m) versus log(c) and 1/n (dimensionless value) is related to the gradient of the graph. Taking the logarithm of both sides' yields:

$$\log (x/m) = \log k + 1/n \log c \qquad (3)$$

The rate of carbon used was determined by dividing the amount of impurity removed by the carbon loading (x/m).

III. RESULTS AND DISCUSSION

A. Efficacy of Carbon Sources

Carbon contents of activated carbon produced were between 80-90%, depending upon the type of the agricultural waste used. The two activated carbons (Figs. 5(a) and 5(b)) were loaded into different filter cartridges. Carbon A (from coconut shells) was the best performing carbon at all impurity concentrations absorbed. The absorbance test results showed that, carbon A is more efficient in adsorbing methylene blue than carbon B (from palm kernel shell). The amount of impurity adsorbed per unit weight of carbon (x/m) was higher than the corresponding value for Carbon B. When methylene blue was used to characterize the mesoporous activated carbons, it was found that, the carbon A were the most mesoporous activated. Fig. 6 is a schematic of the porous structure of an AC [36]. A plot of log (x/m) versus log c from equation (3) gives the results of the isotherm plots shown in fig. 7. Carbon loading (x/m) varied linearly with the impurity concentration from the isotherm plots (Fig. 7).

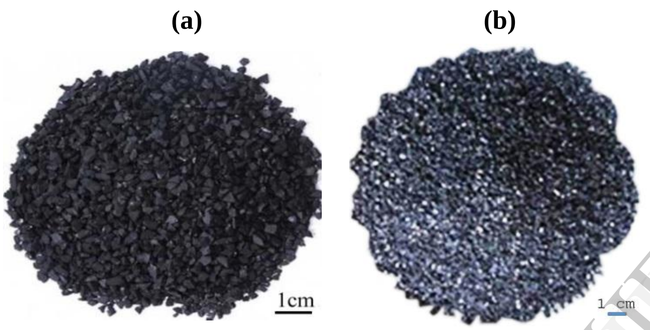

Fig. 5: Granular activated carbon: (a) Obtained from coconut shell, (b) Obtained from palm kernel shell.

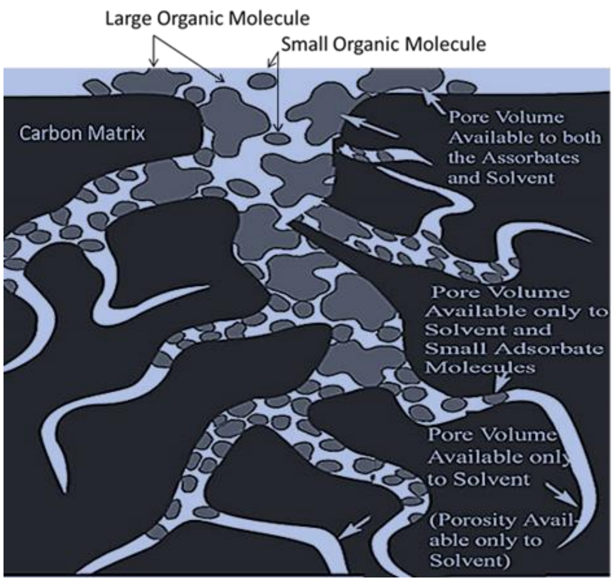

Fig. 6: Schematic of Mesopores in AC. (Modified after Culp et al., 1974).

The constants, k and 1/n were obtained from the graph where n was related to the gradient of the graph given as summarized in table I. The k was related to the intercept on the x/m-axis which yielded 2.77 and 2.09 for carbon A and B, respectively. The value of k is related to the adsorbent capacity, while the value of n is related to the strength of adsorption [35]. The mass of adsorbate per dry unit weight of carbon (x/m) (mg/g) depends directly on k and exponentially on n. The values of n and k reported (Table I) have shown some significant difference in the absorption ability of the carbon sources. Carbon source from coconut shell has a higher adsorbent capacity as compared to the carbon source from palm kennel.

From the Freundlich Adsorption Isotherms [32], the position and slope of the isotherm lines reveal how well one carbon performs relative to the other carbon. The impurities remaining from the isotherm lines (Fig. 7) were lower for carbon A as compared to Carbon B. This ranked Carbon A for a better adsorptive strength than carbon B.

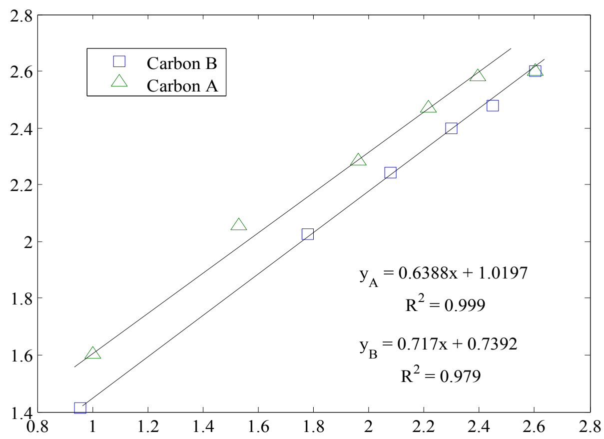

Fig. 7: The plot of Impurites removed versus impurities remaining.

TABLE I. RESULTS FROM ISOTHERM PLOTS

Carbon Type	Adsorbent Capacity, n	Strength of Adsorption, k
A	1.57	2.77
B	1.39	2.09

In other words a nearly vertical isotherm line shows poor adsorptive properties at lower impurity concentrations. After performing several tests on the treated water using the ACs loaded in the filters, the impurity levels were reduced appreciably with AC produced from coconut shells than the one produced from palm kernel. This could be as a result of high adsorption capacity of AC produced from coconut shells than palm kernel. The porous structure of the char was enhanced by using steam as the activating agent for thermal activation according to the following reaction (4):

$$C + H_2O = CO + H_2 \qquad (4)$$

The reactivity of the char is partly attributed to the change in surface area and it increases with the O/C ratio of the precursor.

From the turbidity tests carried out for water samples collected from the two sources (dam water and dugout well), the extent of purification was not the same with AC A. This is probably due to the fact that, the impurity/turbidity level of the water samples collected were not the same as shown in Figs. 8a-c. Higher iodine numbers of carbon A suggest a greater adsorptive ability of carbon A. The lower the impurity levels of the water sample, the higher the extent of purification using the design carbon filter or vice versa.

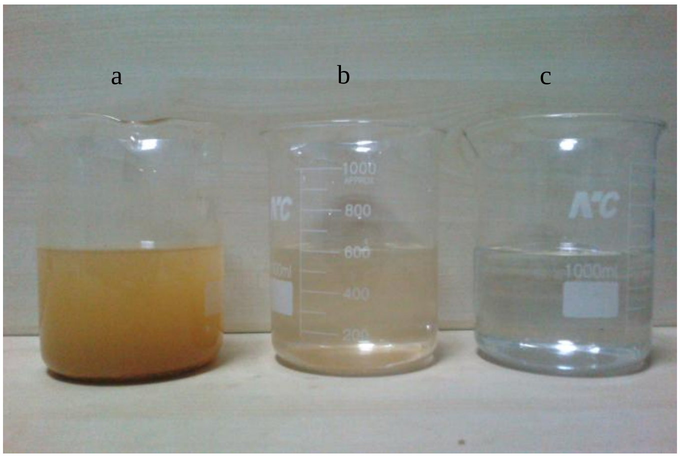

Fig. 8: Water Samples: (a) Untreated Dam Water; (b) Treated

Water from AC filter loaded with AC Obtained from Palm kennel Shells and (c) Treated Water from AC filter loaded with AC Obtained from Coconut Shells.

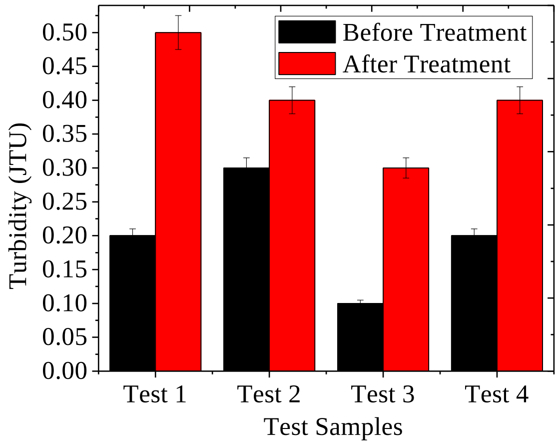

Fig. 9a: Turbidity Test on Dam Water Using AC from Coconut Shells.

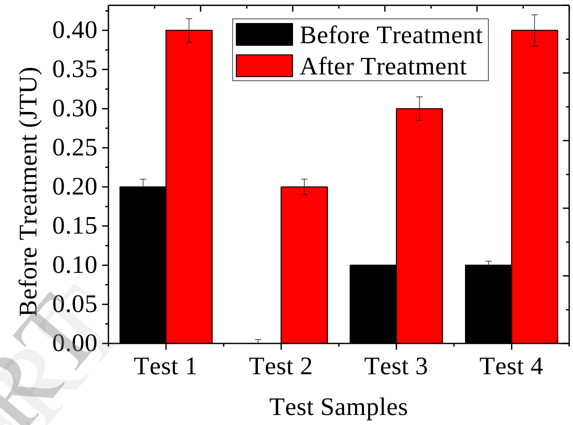

Fig. 9b: Turbidity Test on Dugout Water Using AC from Coconut Shells.

After the Jackson Turbidity Test, water sample collected from dugout (Fig. 9a) and dam (Fig. 9b) were < 5 JTU which satisfied the World Health Organization (WHO) standard [37,38]. WHO defines potable water as water that is clean and transparent, odorless, with no objectionable taste, and free from any kind of microorganism or chemical substance in concentrations that can cause a risk to human health. For the second selected water sample (dam water), the Jackson Turbidity Test was found to be 0.3 JTU. This was due to a high content of impurity levels. This means that, the life span of the AC filter use in treating water from the dugout and dam (located at Dakompilayiri) will last longer if it is used to treat water from the dugout than to treat water from the dam, especially in the dry season where the dam water is majorly polluted by activities such as fishermen and animals (cattle, goats, sheep and pigs). Since the impurity level of the water from the dam is high, the AC used in the filter design has high tendency of being blocked. AC A and impurities removal from water samples from dugout and dam are presented (Figs. 10a-b).

The percentage removal of impurities from a single water sample from a dugout by the two ACs is also presented (Fig. 11). It shows that Carbon A enhance 98 % of impurities compared to 95 % from carbon B. Percentage of impurities removed versus contact time from the dugout water sample is presented in Fig. 11. The result shows that the impurity removal increases with the contact time of water molecule with the carbon. Also from Darcy's law, it was realized that the superficial water flow velocity through the porous medium of AC relate inversely to the thickness of the porous medium. This means that, the velocity of the water passing through the AC can be increased by reducing the thickness of the porous medium or layer in the filter cartridge. However, reducing the thickness of the AC layer in the filter cartridge might reduce the quality of the treated water. The high velocity forced the micro-pores to open, where smaller size organisms in the water can have the chance to pass through the porous medium of the AC.

Water filtration using AC is an adsorptive process in which a contaminant is attracted to and adsorbed onto the surface of the carbon particles. The ability of the adsorption process depends mostly on the features of the carbon which include: particles and pore size, surface area, density and hardness. Moreover, the contaminant characteristics such as the solubility of the contaminant, concentration, the tendency of chemical to leave the water, and contaminant attraction to the carbon surface also play a key role in adsorption process. More importantly, the duration of water and carbon contact affects the contaminant adsorption.

More contact time gives a greater adsorption of contaminants (Fig. 12). This is determined by the water flow rate into/through the filter cartridge containing the AC carbon. Regular check must be carried out to ensure that the AC carbon filter do not get saturated (i.e. when all the adsorption sites on the activated carbon becomes full of contaminants, the filter gets saturated and has reached its capacity). If this happened, contaminants may not be adsorbed any longer by the carbon, but instead contaminants may move from the carbon back into the water.

In this case, it may be that the concentration of the contaminant in the untreated water is less than the treated water. To avoid this effect, it is recommended that, the carbon cartridge in the filter should be replaced.

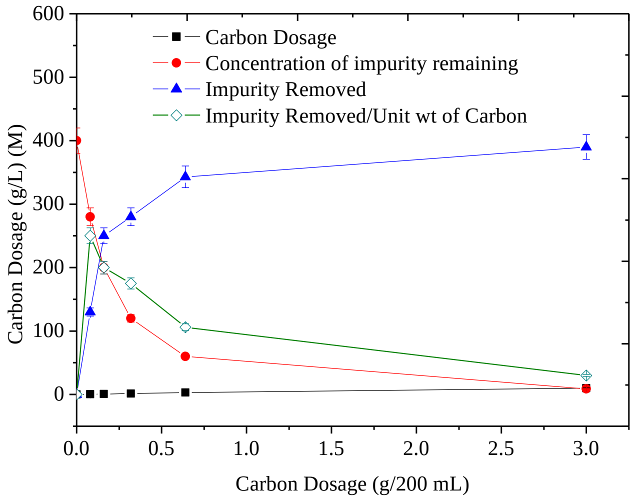

Fig. 10a: Activated Carbon A and Impurities Removal from Water Samples from Dugout.

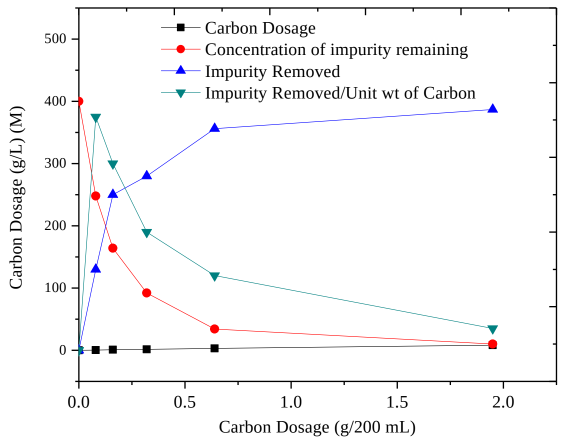

Fig. 10b Activated Carbon A and Impurities Removal from Water Samples from Dam.

C. Statistical Analysis

A statistical test is required to compare the results obtained for carbon A and B. This helps to determine whether if the test result is statistically significant or not. The following hypotheses were drawn for the experiment:

Null Hypothesis (Ho): $\mu_A - \mu_B = 0$
Alternative Hypothesis (Ha): $\mu_A - \mu_B \neq 0$

where μ_A is the mean of water quantity obtained from Carbon A filter, and μ_B is the mean water quantity obtained from Carbon B filter. A paired sample T-test was used to analyze the mean of the percentage removal of impurities obtained from Carbon A and Carbon B water filters. This was achieved by using origin pro 8 software package (OriginLab Corporation, Northampton, MA, USA) in analyzing the test results as illustrated in table II. The probability value of 0.066 is greater than the significance level α of 0.05. At this α-value, the test result was statistically significant, since the difference between their means is not significantly different with the test difference. We therefore fail to reject Ho in favor of Ha and conclude that, the difference in the percentage removal of impurities obtained from Carbon A and Carbon B filters was small. This implies that, the removal of contaminants in water was effective for both coconut and palm kernel shells.

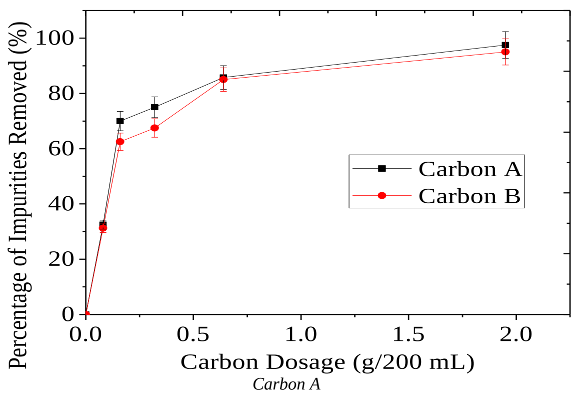

Fig. 11 Percentage of Impurities Removed from the Dugout Water Sample.

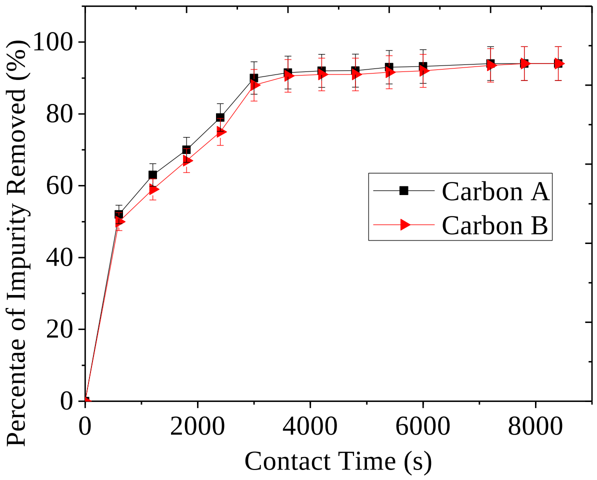

Fig. 12 Percentage of Impurities Removed Versus Contact Time from the Dugout Water Sample.

IV. IMPLICATIONS

Coconut/palm kernel shells are excellent source of raw materials to produce AC due to their high carbon content and hardness. The studies suggest that for an effective removal of impurities or turbidity in water, the carbon filter cartridge should be loaded with AC produced from coconut shells. Following the adsorption test result, it was realized that the palm kernel shells have a low adsorption capacity as compared to coconut shells and as a result all other subsequent analyses were now based on the coconut shell. The AC filter produced locally was only able to remove suspended particles (turbidity) and some other inorganic substances after a laboratory tests were carried on the treated water. The designed calculation for the AC filter shows the filtration rate of treated water is about 2.5 liters/hr. Since treated water can be obtained from the AC filter within the shortest possible time, the design approach presented will be feasible. The data obtained from the adsorption and turbidity tests indicated that AM with favorable physicochemical properties may be produced locally from agricultural waste.

The unit cost of the activated carbon filter produced compared to a clay filter was $18.0. The AC filter produced was more cost effective than the clay filter by a factor of 2.6. There was simply no fuel consumption during the process and that reduced the cost of labor for the filter production.

TABLE II. DESCRIPTIVE AND TEST STATISTICS

	N	**Mean**	**SD**	**SEM**	**t statistic**	**DF**	**Prob>|t|**
% IR	6	60.125	36.744	15.001	2.346	5	0.066
	6	56.875	35.441	14.469			
D		3.250					

[%IR] Percentage of Impurities Removed, [SD] Standard Deviation, [DF] Degree of Freedom, [N] number of Test Data, [SEM] Standard Error of the Mean, [D] Difference.

Furthermore, in the design of the filter, a value for the thickness was assumed and chosen to ensure that a reasonable velocity is achieved through the porous medium. The cross-sectional area at the base was increased relative to the cross-sectional area at the top. This increased the flow rate of the filter. This is known from the relationship between the volumetric flow rate and the cross-sectional area ($Q = \upsilon A$) [39]. By incorporating both Darcy's law and the volumetric flow rate equations, the superficial water flow velocity through the porous AC was found to be 1.615 m/s. 0.056 m^3/s was determined for the volumetric flow rate. This is capable of producing 0.02 m^3 of water in 2 hours.

The micro pores within the activated carbon have the greatest influence upon gas adsorption, while macro pores and mesopores are essential in the transport of fluids to and from the micro pores [12].

V. CONCLUSIONS

In this work, laboratory adsorption testing was the method used to determining how effective the AC produced from coconut shell and palm kernel will be used in the purification process. Preparation of activated carbon from pyrolyzed coconut shell waste was performed in a laboratory-scale facility. The AC produced from coconut shell had a better adsorption capacity than the one produced from palm kernel. AC from the coconut shells were found to be mainly mesopores with irregular, different shapes and sizes for char, and the macropores seemed to be connected to mesopores, especially for a case of palm kernel. This result is in agreement with other studies conducted [40,41].

However, although the AC produced from coconut shells had a better adsorption capacity than the palm kernel shells, the statistical results show no significant difference between them. The test result is statistically significant and the difference in their mean of the percentage removal of impurities is very small and as such, can be omitted.

The methylene blue adsorptions indicate that the AC from coconut shells was shown to be much better. The granular ACs from coconut and palm kernel shells had very similar capacities to adsorb iodine, methylene blue, and residual chlorine, but that from coconut shells was the most effective. The AC from coconut shells was successful to completely eliminate turbidity in water. Home water purification using AC filter is one option that is often used by people who have problems with quality drinking water. AC is considered the best home method, for treating certain organic compounds. However, AC filters have a limited lifetime. Eventually, the surface of the AC will be saturated with adsorbed pollutants, and no further purification will occur.

AC filters is not recommended for metals and other ions that can also be common in drinking water contaminants. These are clearly some of the challenges that should be further investigated. The choice of an AC filter should be based upon, water analysis and a thorough assessment of the individual homeowner's situation. The appropriate filter depth depends on the flow rate of water through the filter. The slower the flow rate, the better the removal. The poor performance of the filter may be due to blockage of the pores with the AC and probably due to improper filter depth. This filter produced can only make used of 1.5 kg of AC to produce 5 liters of treated water within 2 hrs. The incredible properties of AC in addition to the complex metrix/structural network allow it to trap poisons, creosotes, heavy metals, insecticides, bad smells and tastes, chemical substances, and impurities, or undesirable substances in both liquid and gases.

The AC works when ordinary physical filtering (using a sieve, filter paper and filter pads, and sand) cannot separate a particular substance. AC works by adsorbing impurities into its pores. Absorption happens through cooperation of the carbon's enormous adsorptive surface, including its weak electrostatic charges (known as Van der Waals forces) together with the distribution of pores sizes and the construction of the pores surfaces. The carbon pores become saturated with impurities, attaching even to the outside of the carbon.

It should be noted here that no one piece of treatment equipment can manage all contaminants in water. All treatment methods have their own limitations. A combination of treatment processes are required to effectively treat water for human use. It might be stated that different types of carbon and carbon filters remove different contaminants. For instance, AC filters are incapable of removing microbial contaminants (bacteria and viruses), calcium and magnesium (hard water minerals), fluoride nitrate including other compounds. Sedimentation method is therefore recommended in the first place to reduce turbidity before introducing water into a filter. This is because surface water needs pre-treatment to reduce turbidity and this is an added advantage in that, it will prolong the filter-saturation/life time.

REFERENCES

[1] Davey J, McNulty S, Semiao A, "Saving Rural Ghanaian Communities from Waterborne Diseases Using Ultrafiltration", Mondialogo (URL: http://www.org/295.html?L=en. Unpublished, 2009.

[2] C. W. S. (Community water solutions), Ghana (Communitywatersolutions.org), Unpublished, 2009.

[3] C. D. C. (Center for Disease Control and Prevention) "Progress Toward Global Eradication of Dracunculiasis". Morbidity and Mortality Weekly Report (MMWR) Vol.57, 2008, pp1173-1176.

[4] WHO (World Health Organization) "Dracunculiasis Eradication: Global Surveillance Summary": Wlkly Epidemiol Rec. Vol. 84, 2009, pp.162- 167.

[5] GHS (Ghana Health Service), "Annual Report". Government of Ghana through the Ministry of Health, 2011, pp.1-93.

[6] GSSD (Ghana Statistical Service Department), Countries Fact Sheets, (http://www.afro.who.int/home/countries/fact_sheets/ghana.pdf). WHO (World Health Organization), 2003.

[7] T. Sittoni and S. Maina (Editors), "Economic Impacts of Poor Sanitation in Africa", WSP (Water and Sanitation Program), 2012, pp.1-5.

[8] M. Kosek, C. Bern and R. L. Guerant "The Global Burden of Diarrheal Disease, As Estimated from Studies Published between 1992 and 2000", Bulletin of the World Health Organization, Vol. 81, No. 3, 2003, pp.197-204.

[9] WHO (World Health Organization) "Global Water Supply and Sanitation Assessment. Geneva", WHO, 2000.

[10] STKDCA (Sawla-Tuna-Kalba District Assembly) (sawlaghanadistricts.gov.gh.), 2006, unpublished.

[11] M. Kamrin, H. Nancy, C. Barry, B. Dan and D. W. Q. Frank "Home Water Treatment Using Activated Carbon, Cooperative Extension Service", Michigan State University, Vol. 23, 1990.

[12] Z. Hu, M. P. Srinivasan, "Mesoporous high surface area activated carbons". Microporous Mesoporous Mater. Vol. 34, 2001, pp.267-275.

[13] G. Strand, "Activated Carbon for Purification of Alcohol: and Some Useful Distillation Tips", www.homedistllation.com/freebook.htm, unpublished, 2001.

[14] Mendez M O A, Lisboa A C L, Coutinhoand A R, and Otani C, "Activated Petroleum Coke for Natural Gas Storage", J. Braz. Chem. Soc., Vol. 17, No. 6, 2006, pp.1144-1150.

[15] Inagaki M, Kang F, Toyada M and Konno H, (), Advanced Materials Science and Engineering of Carbon, 1st Edition, 2013, p.440, ISBN: 978-0-12-407789-8.

[16] O. A. Shenderova, V. V. Shirnov and D. W. Brenner, "Carbon Nanostructures", Critical Reviews in Solid State and Materials Sciences, Vol. 27 No.3, 2002, pp.227-356.

[17] N. Sevage. Materials Science: Super Carbon. Nature 483. 2012, pp.30-31. Doi: 10.1038/483s30a.

[18] D. D. L. Chung, Composite Materials: Science and Applications. Second Edition. Springer, 2010, p.370, ISBN: 978-1-84882-830-8.

[19] A. C. Lua and J. Guo, "Mircroporuos Oil-Palm-Shell Activated Carbon Prepared by Physical Activation for Gas-Phase Adsorption", Langmuir, Vol. 17, No. 12, 2001, pp.7112-7117.

[20] M. I. Yusufu, C. C. Ariahu and B. D. Igbabul, "Production and characterization of activated carbon from selected local raw materials", African Journal of Pure and Applied Chemistry, Vol. 6, No. 9, 2012, pp.123-131.

[21] I. K. Adewumi, "Activated Carbon for Water Treatment in Nigeria: Problems and Prospects", E. K. Yanful (Ed), Appropriate Technology for Environmental Protection in the Developing World. Springer Science and Business Media B.V., 2009, pp.115-122.

[22] C. Dileck, A. Y. Oznuh "Production and characterization of activated carbon from bituminous coal through chemical activation", Afr. J. Biotechnol., Vol. 7, No. 2, 2008, pp.3703-3710.

[23] I. D. Bruce and O. S. Sharon, "Drinking Water Treatment: Activated Carbon Filtration", Revise Version, University of Nebraska Lincoln, NebGuid 1489, 2013.

[24] G. Leopold, "Hand-Book of Chemistry". Harrison and Sons, London, 4th Edition, Vol. 7, 1848, pp.4-501

[25] EPA (Environmental Protection Agency)-USA, "Water Health Series: Filtration Facts", www.epa.gov/safewater, 2005.

[26] R. B. Lartey and A. Francis, "Developing National Capability for Manufacture of Activated Carbon from Agricultural Wastes", the Ghana Engineer, 1999.

[27] GSSD (Ghana Statistical Service Department), 1997, unpublished.

[28] H. M. Mozammel, O. Masahiro and S. C. Bahattacharya "Activated Charcoal from Coconut Shell Using $ZnCl_2$ Activation, Biomass Bioenergy Vol. 22, 2002, pp.397-400.

[29] MOFA (Ministry of Food and Agriculture) "Agriculture in Ghana: Facts and Figures", 2011, pp.1-52.

[30] E. Myre and R. Shaw (2006), "The Turbidity Tube: Simple and Accurate Measurement of Turbidity in the Field". Michigan Technological University.

[31] WHO (World Health Organization) (2004), "Guidelines for Drinking-water Quality", 3rd Ed: Geneva, Vol. 1.

[32] J. Davis and L. Robert Engineering in Emergencies: A Practical Guide for Relief Workers, 2nd Edition. Warwickshire, UK: RedR / ITDG Publishing, 2002.

[33] D. Dang, W. Ding, A. Cheng, S. Liu and X. Zhang "Isotherm Equation Study of F Adsorbed from Water Solution by $Fe_2(SO_4)_3$-modified Granular Activated Alumina. Separation Science and

Engineering", Chinese Journal of Chemical Engineering, Vol. 19, No. 4, 2011, pp.581-585.

[34] A. Violante, P. M. Huang, G. M. Gadd, "Biophysico-Chemical Processes of Heavy Metals and Metalloids in Soil Environments", Wiley-Interscience, America, Vol. 217, 2008.

[35] W. J. Jr. Weber, Physicochemical Processes for Water Quality Control. Wiley Interscience, John Wiley and Sons Inc., New York, NY, 1972.

[36] L. C. Russell., L. C. Gordon, "New Concepts in Water Purification". Van Nostrand Reinhold Co., New York, USA, 1974.

[37] WHO (World Health Organization) "Burden of Disease and Cost-Effectiveness Estimates", 2010.

[38] UN (United Nation), "Water in a Changing World", World Water Development Report, UNESCO Publishing, (http://www.unesco.org/water/wwap), 2003.

[39] B. R. Munson, D. F. Younf, T. H. Okiishi and W. W. Huebsch, Fundamentals of Fluid Mechanics. 6th Edition. John Wiley and Sons, Inc. USA, 2009, ISBN 978-0470-26284-9.

[40] Norit Americas Inc. Norit Activated Carbon Data Sheet. Hydrodarco 4000. http://www.norit-americas.com/pdf/HD4000_rev6.pdf, 2007a.

[41] Norit Americas Inc. Norit Activated Carbon GAC 1240 Plus. http://www.norit-americas.com/pdf/GAC1240_rev6.pdf,2007b.