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Full Length Research Article

PRODUCTION AND PURIFICATION OF WATER USING NATURAL BASED ADSORBENT FROM PLANTAIN PEELS

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ABSTRACT
Activated charcoal or carbon commonly employed as filter examinant of water, and air with surface area of 300–2,000m^2/g, adsorbs a wide range of impurities and contaminants. This study was undertaken to produce adsorbent from plantain peels (Natural based), for the treatment of water samples, subsequently tested. Pyrolysis activation method was adopted using H_3P0_4 and KOH. Water samples of wells from Gonigora, boreholes from Ungwan Romi, fishponds from Kawo and Kaduna Polytechnic, river water from river Kaduna, rain, tap from Tudun Wada and Eva water from Coca-Cola were used for the analysis. Which include water treatment, pH determination, total suspended, total dissolved, and total volatile solids, colour and odour determination. The results showed activated carbon effectiveness on pH of water samples well within 7.00, for borehole, Tap, and 7.02, for pond, rain and Eva waters, while 7.10 for river water. This indicated that the adsorbent is active and compared favorably with the standard adsorbent which pH of the water samples treated were 7.00 for pond, rain, tap and Eva, while 7.02 and 7.04 for borehole and river water respectively. This validated the production of granular natural based adsorbent via pyrolysis of plantain peels at 450^{0}C by chemical activation method. Therefore an economical adsorbent obtained naturally based as cheap, readily available waste material for future commercial purification application.

Keywords: Pyrolysis, Plantain peels, water treatment, KOH, Phosphoric acid and Activated Carbon

INTRODUCTION
Activated carbon (AC) is a tasteless, solid, microcrystalline, non-graphite form of black carbonaceous material with a porous structure. It has been a unique adsorption substance because of its high capacity and versatile degree of surface reactivity (Williams and Reed, 2006). Activated carbon's large porous surface area and its controllable pore structure make it suitable for wastewater treatment. Such porosity facilitates the uptake of dyes, explaining the chemical properties of dye and the crucial role of activated carbon in the interactions that occur between the adsorbate and the adsorbent (Kadivelu and Namasivayam, 2003).

Activated carbon has numerous applications, which includes but not limited to liquid phase application, Gas phase application, reduction of industrial air pollution, production of electrode and batteries, in liquids phase application and for the treatment of industrial wastewater, such as, textile manufacturing wastewater (Kadivelu and Namasivayam, 2003). Granular activated carbon, or charcoal, is widely used to treat waste water to remove organic or inorganic pollutants and heavy metals because of its large specific surface area, high adsorption capacity, and special surface chemical properties (Muiz and Martinez, 2004). It has been prepared from various raw materials that have high carbonaceous content. These include maize, cob, and wood; sawdust; bone; coconut shells; coir pith; nutshells; almond shells; peanut husks; and plantain peel (Nurul and Ekinci, 2007).

Because it is a commonly farmed food crop in countries within the West African sub-region, plantains are particularly numerous and easily available, accessible from dump sites to local farmers and dealers in the nation. Furthermore, the process of converting it into activated carbon uses less energy and takes less time than producing charcoal from bones and other woody materials (Spalding and Deng, 1998).

According to Zuo *et al.* (2009), raw materials with high organic content are typically used to produce activated carbon. Physical activation and chemical activation are the two fundamental ways activated carbon can be prepared. The objective of this study is to synthesize activated carbon from plantain peels for the purpose of treating water.

MATERIALS AND METHODS

Sample Collection and Treatment
The samples of plantain peels were collected from Romi Market, Television Market, and Romi Bus Stop in Kaduna metropolis in June 2019. Well water from Gonigora residential area, borehole water from Romi market street, tap water from the ostrich bakery opposite Kaduna Polytechnic, rain water direct from the sky, river water from the Kaduna Nasarawa area, and river pond water from Kaduna Polytechnic Applied Biology Biological Garden.

Production of Activated Carbon
The preparation of activated carbon used for water purification was done by subjecting the plantain peels to incomplete combustion, as described by Sugumarari and Seshadri (2011). briefly described as follows: Plantain peels were cut into pieces and rinsed thoroughly with distilled water to remove debris and other impurities. The plantain peels were dried in an oven to a constant weight at a temperature of 105 °C for 24h after which they were crushed to a fine powder, sieved, and used for the production of activated carbon (Sugumarari and Seshadri, 2011).

Chemical Activation
The crushed plantain peels were divided into two parts: the first was mixed with 20% phosphoric acid (100g of sample added to 100 mL of phosphoric acid), and the second part was mixed with 20%

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potassium hydroxide (100g of sample added to 100 mL of potassium hydroxide). The samples were pyrolyzed at 450 °C for one hour in an electric muffle furnace. After activation, the mixture was removed from the furnace and allowed to cool to room temperature at 25 °C. The pyrolyzed carbons were leeched with 2% HCl for two hours and washed several times with distilled water until a neutral pH was achieved. Later, the carbon paste was dried in an electric muffle oven at 110 °C for two hours. The weight of the activated carbon after activation was obtained (Moline *et al*., 2000).

The percentage yield of activated carbon was calculated by applying the formula.

$Y_c = \frac{100w_c}{w_0}$

Where Yc is the percentage yield, Wc is the weight after activation, and Wo is the weight before activation (Budinova and Wigman, 2006).

Preparation of Standard- Solutions.

Calcium hydroxide solution (lime water) was prepared by adding 5g of calcium hydroxide weighed and quantitatively transferred into a 100-mL volumetric flask. The flask was filled with distilled water and shaken vigorously for 2 minutes and then left for 24h.

Chlorine water solution was prepared by hypochlorite and hydrochloric acid mixed together. The equilibrium lies toward Cl_2 in the reaction.

$HOCl + HCl$ ----------> Cl_2 + H_2O.

Potassium hydroxide solution was equally prepared by adding 20g of potassium hydroxide, weighed and quantitatively transferred into a 100-mL volumetric flask, and diluted with distilled water.

Phosphonic acid solution (20%) was prepared by measuring 20 mL of phosphoric acid with a measuring cylinder and transferring it into a 250 mL breaker. 100 mL of distilled water was measured into another beaker, and 20 mL of phosphoric acid was added to the 100 mL of distilled water and swirled.

Procedure for Water Purification

The standard steps given by the World Health Organization (WHO, 2006) and the Environmental Protection Agency (EPA, 2009) in the United States for water treatments considered are listed below.

(1) Coagulation and flocculation
(2) Sedimentation
(3) Filtration
(4) Disinfection

One hundred milliliters (100 mL) of each water sample was measured with a measuring cylinder and transferred into a clean beaker. 0.05g of aluminum sulfate, $Al_2(SO_4)_3$ (alum), was added to each sample and stirred for 15 minutes, then allowed to sand for 30 minutes. Five drops of calcium hydroxide (lime water) $Ca(OH)_2$ were added to each beaker and allowed to stand for another 5 minutes, after which it was filtered with filter paper into another volumetric flask. The filtered water sample was allowed to stand for 2 minutes, after which 5 drops of chlorine water were added to each beaker containing the water sample. An activated carbon filter was made with the produced activated carbon, and each water sample was filtered again. The mixture was allowed to stand for 30 minutes for precipitation and coagulation to take place. After the mixture was allowed to sit for 30 minutes, the granular activated carbon was added to the beakers containing the water samples for purification and clarity purposes.

The supernatant (the liquid above the sediment) of each sample was filtered using filter paper. The water samples were aerated by turning them into another beaker, and 0.5 mL of chlorine water was added. After which, the pH of the samples was taken (EPA, 2009).

Determination of Total Dissolved Solid (TDS)

The crucible was washed and placed in an oven at 105 °C for one hour. It was then removed and kept in a desiccator for 30 minutes to cool. The weight W1 was taken, and 25 mL of the sample was taken into the crucible. The crucible with the sample was heated on a thermoplate until all the liquid evaporated. The crucible was taken back into the hot air oven at 105 oC for another hour. It was then cooled in a desiccator for 30 minutes. The weight W2 was taken, and the total dissolved solid was then calculated using the formula below:

TDS in mg/l = weight of crucible and sample after combustion – weight of empty

$= \frac{\text{crucible x standard}}{Volume\ of\ H_2O\ used}$ (Note:- 1.0×10^6 is a standard) (EPA, 2009).

Determination of Total Suspended Solid (TSS)

Fitter papers were kept in the oven at 75 °C for 30 minutes, then removed and kept in a desiccator for another 30 minutes to cool. The weight W1 was taken, and 25 mL of the sample was taken and filtered through the weighed filter paper. The filtered paper and residue were kept in an oven at 75 °C for 30 minutes and finally placed in the desiccator for 30 minutes, and the weight was taken as W2 (EPA, 2009).

Determination of Total Volatile Solid (TVS)

The weight of dried residue in TDS was recorded as Wd, and the weight of the crucible and water after combustion in the muffle furnace was recorded as Wc.

TVS was calculated by subtracting Wc from Wd.

Total volatile solid = total dissolved solid – weight of crucible and H_2O after combustion in muffle furnace.

$= \frac{\text{Wd- Wc x standard}}{\text{Volume of } H_2O}$ (EPA, 2009) .

pH Determination

The pH was determined at atmospheric temperature (28 °C), the electrode was washed with fresh distilled water, and the instrument was calibrated or standardized. The various samples were tested one after the other using a small beaker. After the pH of a sample was determined, the electrode was washed before determining the next sample (Jensen *et al.,* 2019).

pH Determination of the Produced Granular Activated Carbon

The pH of the activated carbon was determined using standard methods. One gram of the activated carbon was suspended in 50 mL of distilled water and heated to 90 oC while stirring for 20 minutes. The suspension was allowed to cool to room temperature, and the pH was obtained by inserting the probe of the pH meter into the solution (Zhang and Prahas, 2005).

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RESULTS AND DISCUSSION

Activated Carbon Yield from Plantain Peels

Table 1 below displays the figures of the activated carbon yield from plantain peels. Following activation, the percentage yield for the potassium hydroxide and phosphoric acid procedures was 93.6±0.13% and 89.5±0.20%, respectively. The table also presents the pH of the activated carbons to be 7.0±0.01 and 7.0±0.02 in the two cases, indicating neutral values, and equally shows that a reasonably high pH of quality water was obtained after water purification. In the activated carbon production carried out at a temperature of 450 °C for plantain peel impregnated with phosphoric acid (H_3PO_4), a minimum weight loss occurrence was observed, going by the yield obtained as 89.5±0.20% for potassium hydroxide (KOH) and 93.6±0.13%, indicating that the activating agent is the best choice for the chemical activation process widely used in the production of activated carbon with higher yields as well as easy recovery of the activating agent (Williams and Reeds, 2006). The activation agents are reported to act as an acidic/alkaline catalyst to promote bond cleavage, hydrolysis, dehydration, and condensation, accompanied by a cross-linking reaction between acid/alkaline and biopolymers (Lozano *et al.,* 2001).

Table 1: % Yield of Activated Carbon from Plantain Peels Using Two Different Activation Methods

Activation waste material	Activation method	Percentage yield (%)	Activated carbon pH
Plantain peels	H_3pO_4	89.5±0.20	7.0±0.01
Plantain peels	KOH	93.6±0.13	7.0±0.02

The values are presented in mean±SD n=3

The Treatment of Raw Water Samples using the Activated Carbon Produced from Plantain Peels

The values of the analyses performed on the water sample are presented in Table 2. The pH result showed a slight variation between the pH of the purified water sample and the raw water. However, those of the well, rain, and tap water samples all show the same pH values. On the other hand, borehole, river, and Sold bottled water have similar pH values of 7.02±0.01, while pond water pH is unique and higher with a value of 7.10±0.05. Despite the variation, the results still indicated a normal pH for drinking water. On set, before the analysis, it was observed that well water was cloudy, while pond water was greenish, and river water was chocolate in color. while rain, tap, and Sold bottled water were colorless. However, after purification, all the water samples were colorless, tasteless, and odorless (Table 2). The values of the water bodies presented in Table 2 after purification are in conformity with the Environmental Protection Agency's (EPA) recommended values (www.healthline.com). The agency recommended that healthy water be colorless, odorless, and tasteless, which showed that the purified water is healthy for drinking.

Table 2: The physical appearance and the mean values of pH of water samples before and after treatment using the produced activated carbon

Sample Name For Water	PBP	PAP	CSBP	OSBP	CSAP	OSAP
Well water	6.56±0.01	7.00±0.01	Cloudy	Offensive	Colourless	Nil
Bore hole	6.85±0.03	7.02±0.01	Colourless	Nil	Colourless	Nil
Pond water	6.58±0.02	7.10±0.05	Green	Offensive	Colourless	Nil
River water	6.60±0.01	7.05±0.02	Chocolate or carton	Offensive	Colourless	Nil
Rain water	6.64±0.02	7.00±0.02	Colourless	Nil	Colourless	Nil
Tap water	6.90±0.02	7.00±0.01	Colourless	Nil	Colourless	Nil
Soldbottled water	6.85±0.01	7.02±0.02	Colourless	Nil	Colourless	Nil

The values are presented in mean±SD n=3

Key: PBH:pH Before Purification. **PAP**: pH After Purification. **CSBP**: Color of Sample Before Purification. **OSBP:** Odour before purification. **Odor Color** After Purification. **OSAP**: Odor After Purification

The Treatment of Raw Water Samples Using the Standard Activated Carbon

The values of the analyses performed on water treated with standard activated carbon are presented in Table 3 below. The recorded pH of well, pond, rain, and tap water had a pH value of 7.00±0.01, borehole water and sold bottled water had a pH value of 7.02±0.01, and river water had a pH value of 7.04±0.02 after purification. It was indicated that the well water was cloudy, the pond was greenish, and the river water was chocolate before purification. However, they all become colorless after purification. The odor of the well and pond water were both offensive before purification, but after purification, all the water samples became odorless (Table 2). In Table 3, the recorded physical properties of the water treated with standard activated carbon were recorded, and the pH was similar to the results of water treated with produced activated carbon from plantain peels, which indicated that the produced activated carbon from plantain peel is very active and can compete favorably with the standard activated carbon. The pH of the water treated with standard activated carbon ranged from 7.00±0.01 to 7.04±0.02, respectively, which is in accordance with the standard recommended by the Environmental Protection Agency (EPA) (www.healthline.com) and eventually supported that healthy water must be colorless, odorless, and tasteless.

Table 3: The physical appearance and the mean values of pH of the water samples treated using the standard activated carbon

Sample Name For Water	PBP	PAP	CSBP	OSBP	CSAP	OSAP
Well water	6.90±0.01	7.00±0.01	Cloudy	Offensive	Clourless	Nil
Borehole water	6.91±0.02	7.02±0.01	Clourless	Nil	Clourless	Nil
Pond water	6.55±0.01	7.00±0.02	Green	Offensive	Clourless	Nil
River water	6.91±0.03	7.04±0.02	Chocolate	Nil	Clourless	Nil
Rain water	6.54±0.01	7.00±0.01	Colourless	Nil	Colourless	Nil
Tap water	6.80±0.02	7.00±0.01	Colourless	Nil	Colourless	Nil
Eva water	6.85±0.03	7.00±0.01	Colourless	Nil	Colourless	Nil

The values are presented in mean±SD n=3

Key: PBH:pH Before Purification. **PAP**: pH After Purification. **CSBP**: Color of Sample Before Purification. **OSBP:** Odour before purification. **Odor Color** After Purification. **OSAP**: Odor After Purification

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Total Suspended, Dissolved, and Volatile Solids for Water Treatment with the Produced Activated Carbon from Plant Peels

The result obtained for total suspended solids as presented in Table 4 shows that river water has the highest value of TSS, which is 21,720±1.7 mg/L, followed by pond water, which has 20,720±1.5 mg/L, 4,120 mg/L, and borehole water has the lowest TSS, which is 520 mg/L, respectively. Rain water has 21,720 mL, well water has 1760±0.6 mL, tap water has 1680 mL, and sold bottled water has.

The values of the total dissolved solids show that well water, pond water, and river water have the highest TDS, which is 120 mg/l, while borehole water, rain water, and tap water have the value of 80 mg/l, and Eva water has the lowest TDS value of 40 mg/l, respectively (Table 4).

On the other hand, the total volatile solids for well and river water were the highest at 120 mg/l. Borehole water, pond water, and rain water have 80 mg/l, while tap water and Eva water indicated the lowest TVS of 40 mg/l (Table 4).

Table 4 shows the results of the total suspended solids of different water samples, which are 520, 1680, 1760, 4,120, 6440, 20,720, and 21,720 mg/L, based on the standards set by the World Health Organization (WHO/SDE/WSH/03.04/16) and the International Organization for Standardization of Water Quality (150 7888: 1985).

Table 4: Total Suspended Solid for Sampled water Bodies treated with the Prepared Activated Carbon

Sample name	Site name	TSS (mg/L)	TDS (mg/L)	TVS (mg/L)
Well water	Gonigora site	1760±0.6	120±0.8	120±0.9
Borehole	Ungwanromi site	520±0.6	80±0.8	80±0.7
Pond water	Kaduna Polytechnic	20,720±1.5	120±0.6	80±0.82
River water	Nasarawa river	21,720±1.7	120±0.6	120±0.9
Rain water		6440±0.6	80±0.8	80±1.2
Tap water	Tundunwada	1680±0.6	80±0.8	40±0.8
SoldBottled water	Coca cola water	4120±1.2	40±0.5	40±0.3

The values are presented in mean±SD n=3
Key: TSS: **Total Suspended Solid TDS: Total Dissolved Solid TVS: Total Volatile Solid**
Note: $1.0x10^6$ is a standard, and the values are in mg/l

Total Suspended, Dissolved, and Volatile Solids for Water Treated with Standard Activated Carbon

The results in Table 5 below show the values of TSS for the water treated with standard activated carbon. Total dissolved solids and total volatile solids of water treated with standard activated carbon. Pond water has the highest TSS of 21,720 mg/l; Eva water and rain water have the lowest TSS of 520 mg/l; borehole water has 6,440 mg/l of TSS. Well water and tap water have the same TSS of 1680 mg/l, while borehole water has a TSS of 6,440 mg/l.

The result shows that rain water has the highest TDS of 120 mg/l, while pond water has the lowest TDS of 40 mg/l, and well water, borehole, river water, tap water, and Eva water indicated the same TDS value of 80 mg/l, respectively. The results also show that rainwater has the highest TVS of 120 mg/l. But pond water, river water, and tap water had the lowest TVS of 40 mg/l, while well water, borehole water, and Eva water indicated the same TVS of 80 mg/l, respectively (Table 5).

Table 5: Average values of TSS, TDS, and TVS for water samples treated with standard activated carbon

Sample Name	TSS (mg/L)	TDS (mg/L)	TVS (mg/L)
Well water	1680±0.6	80±0.8	80±0.7
Borehole	6,441±0.6	81±0.8	81±0.8
Pond water	21,721±1.7	41±0.5	41±0.5
River water	1760±0.6	80±0.8	40±0.8
Rain water	521±0.6	120±0.8	120±0.8
Tap water	1681±1.2	80±0.5	40±0.5
Eva water	521±1.2	80±1.4	80±0.5

The values are presented in mean±SD n=3
Key: TSS: **Total Suspended Solid TDS**: **Total Dissolved Solid** TDS: **Total Volatile Solid**
Note: $1.0x10^6$ is a standard, and the values are in mg/l.

In Table 5, reasonable values of total dissolved solids were obtained, which ranged from 40, 80, and 120, respectively, which is in accordance with the standards given by the World Health Organization (WHO/UNEP, GEMS, Global Fresh Water Quality), (Schroeder HA, Municipal Drinking Water, and Cardiovascular Death Rates). These organizations that were mentioned above set a standard value for healthy drinking water based on the research they conducted. The World Health Organization says the palatability of drinking water is rated by panels of tasters in relation to its Total Dissolved Solid Level (TDS) as follows: excellent, less than 300 mg/liter; good, between 300 and 600 mg/liter; fair, between 600 and 900 mg/liter; and uneatable, greater than 1200 mg/liter. These showed that the results gotten from the treated water were excellent, in accordance with the World Health Organization's (2006) global fresh water quality, as shown in Table 5. In Table 5, the results of total volatile solids correspond to those of the Environment Protection Agency. These results ranged from well water (120 mg/l), borehole water (80 mg/l), pond water (80 mg/l), river water (120 mg/l), rainwater (80 mg/l), tap water (40 mg/l), and Eva water (40 mg/l), respectively, which showed that the results were in accordance with the standard of water quality given by the EPA/Environmental Protection Agency. (www.healthline.com), International Organization for Standardization of Water Quality (ISO 7888:1985).

Values of TVS, TDs, and TVS in Table 5 show that water treated with standard activated carbon corresponds with the values obtained in water treated with the produced activated carbon. These results are in accordance with the standards of the Environmental Protection Agency (EPA) (healthline.com) and the World Health Organization (WHO) Global Fresh Water Quality (2006), Municipal.

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