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Comparative Study of Three Differently Produced Activated Carbons from *Borassusaethiopum*

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Abstract: This study was initiated with the aim of helping rural populations in the production of an activated carbon capable of depolluting water on an ad hoc basis. *Borassusaethiopum*carbon, with a carbon content of 71%, was selected in contrast to manioc can charcoal, which has a carbon content of 56%. After producing activated carbon using three methods (i.e. carbon impregnation and hot washing, steam activation and impregnation followed by kiln drying at 450 °C(CAF)), the chemical activation method with kiln intervention proved to be the most effective. This choice was based on COD removal rates. COD removal rates of 57.61, 87.46, 51.04 and 74.32 were obtained by considering experiments 1, 2, 3 and 4. Turbidity was also reduced to the WHO standard using CAF.

Keywords:rural populations, activated carbon, depolluting water, *Borassusaethiopum*, COD removal, impregnation

1. INTRODUCTION

Water is a resource which, despite considerable progress, remains difficult to access for some of the world's populations. Today, although water is available, its quality remains uncertain. This situation is exacerbated by the galloping growth of the world's population, especially in Africa, estimated at over 8 billion [1] , and more specifically in sub-Saharan Africa, where it has increased by 2.5 % [2]. There is no shortage of solutions, but they are either expensive or difficult to apply, especially in rural areas. Among the solutions we can cite the electrocoagulation method applied by [3,4] for phosphate and nitrate removal. Also, Photocatalysis, a method based on the consumption of photons of energy by a semiconductor is used for water treatment [5]. However, as pointed out by [6], photocatalysis, like electrocoagulation, has its limitations. It is only effective for COD concentrations below 5 g/L and requires high energy consumption. As for electrocoagulation, it generates sludge that has to be managed at the end of the treatment process. Faced with these difficulties, which limit the use of these methods, especially in rural areas, we have opted for the use of activated carbon. Charcoal filters have been

designed from local materials for treatment in rural areas. Three activated carbons were used for this purpose. The general aim of this study is to compare the efficiency of three different activated carbons. Specifically, the aim is to select the best precursor, produce activated carbons by three different methods from the chosen precursor and characterize this carbon, then select the best after a COD removal test.

2. MATERIALS AND METHODS

All the equipment used to analyze the chemical and physical parameters is summarized in table 1.

Table 1:
Equipment used to analyze the chemical and physical parameters

Designation	*Brand*	*Serial No.*	*Origin*
Balance	Scout pro	123	China
Spectrophotometer	JASCO UV-visible	J350	Japon
Oven	Memmert	190	West Germany
Turbidimeter	HANNA	HI 93703	Spain
pH meter	HANNA	HI 8424	Spain
Conductimeter	HANNA	HI 9835	Spain
COD meter	DRB	300	Spain
Artisanal oven	-	-	Ivory Coast
Rônier branches	-	-	Ivory Coast
Artisanal filter	-	-	Ivory Coast

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2.1. Methodology

2.1.1. Choice of precursor

Two materials were selected for the precursor. Cassava skins and roast tree branches were the main precursors. The specific surface areas and scanning electron microscopies of the two activated carbons were determined.

2.1.2. Carbon preparation

Collected roast branches were cut into small pieces and washed with tap water. These pieces were spread out on a black tarpaulin to dry in the sun for almost 4 days. After drying, they were placed in a traditional oven previously heated to a temperature of 200 °C and carbonized at between 400 and 500 °C for a period of 5 hours. The charcoal obtained was removed from the kiln after the temperature in the kiln chamber had been reduced, then placed in a desiccator for cooling. Once cooled, it was cleaned of dust, sand grains, ash and other impurities by washing with boiling water, then placed in an oven at 105 °C to dry the wet samples for 24 hours, and ground and sieved to obtain grains with a diameter between 0.1 and 0.

Figure 1: Production method for non-activated carbon

2.1.3. The different forms of carbon activation

2.1.3.1. Physical activation of carbon

This procedure, which did not require the use of chemicals, was carried out using the device described in figure 2. First, distilled water is introduced into the lower flask. Next, a 100 g mass of granular carbon was weighed and introduced into the upper part. Then, the device was switched on to activate boiling of the water for 5 h. Finally, the charcoal was oven dried at 105 °C for 24 h. This simple method can be applied in rural areas using the "attiéké" cooking device.

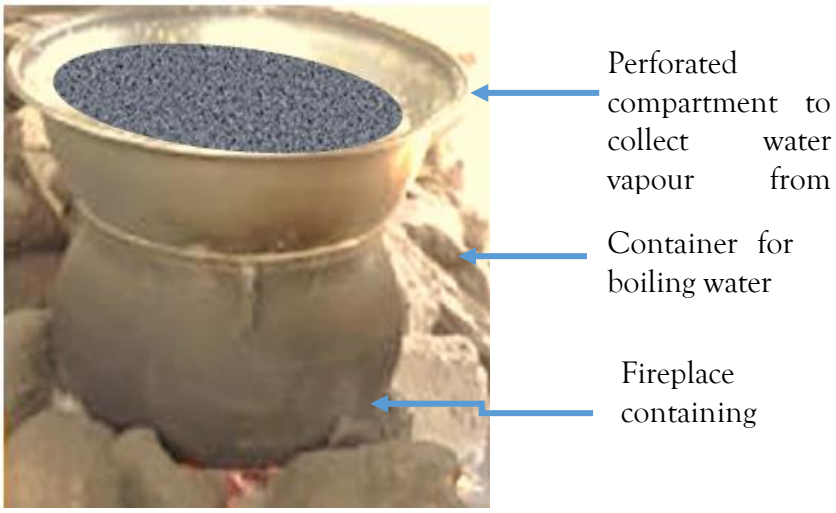


Figure 2: Physical method for preparing activated carbon

2.1.3.2. Simply impregnated and hot-washed charcoal

Chemical activation of the charcoal was carried out by impregnating 3 kg of granular charcoal in 3 L of a 1000 ppm copper sulfate solution for 24 hours. The impregnated coal was then hot-washed. To 200 g of raw CA, 3 L of water was added, and the whole was boiled for 2 h. A total of 5 washes were necessary. An additional rinse treatment was applied to bring the pH towards 7. This operation was repeated 5 times. Finally, the charcoal was oven-dried for 24 h at 105 °C to make it ready for use.

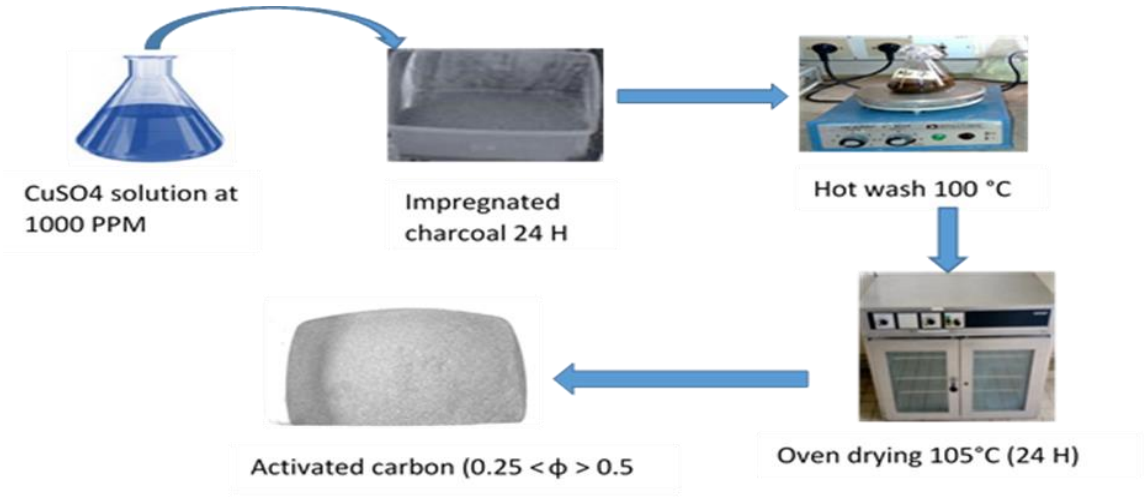


Figure 3: Coal preparation without the furnace

Chemical activation of the charcoal was carried out by impregnating 3 kg of granular charcoal in 3 L of a 1000 ppm copper sulfate solution for 24 h. The impregnated charcoal was then heated to 450 ± 10 °C for 3 h in the artisanal kiln. The activated charcoal thus obtained underwent hot washing. To 200 g of raw AC, 3 L of water was added, and the whole mixture was boiled for 2 h. A total of 5 washes were necessary. An additional rinse treatment was applied to bring the pH towards 7. This operation was repeated 5 times. Finally, the charcoal was oven-dried for 24 h at 105 °C, ready for use

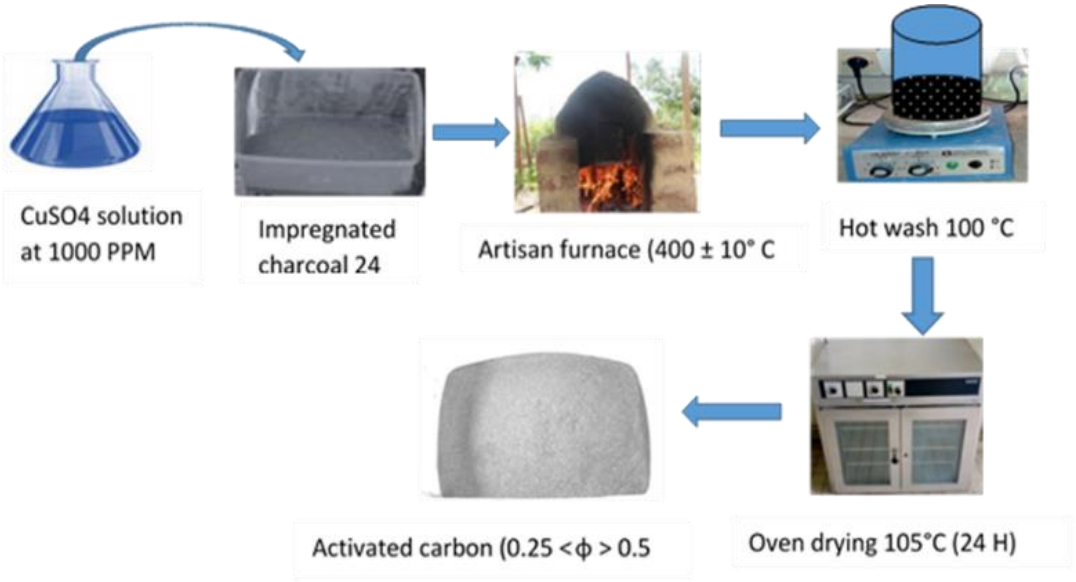


Figure 4: Activation process for *Borassusaethiopum* activated carbon

2.1.4. Sand treatment

The collected sand was first sieved using sieves (prolabo, AFNOR 05028282) with diameters of 0.25 mm and 0.5 mm to obtain different grain sizes. Sand samples with diameters between 0.25 mm and 0.5 mm were classified as coarse sand, while those with diameters below 0.25 mm were classified as fine sand. Both types of sand were then subjected to chemical treatment with a hydrogen peroxide solution at pH 1.38 to remove organic matter.

To achieve this, the samples were soaked in the hydrogen peroxide solution for 24 h at room temperature, followed by a thorough wash with distilled water until the pH of the rinsing water

approached 7. The sands obtained were oven-dried for 24 h at 105 °C. All the sand processing stages are shown in Figure 5.

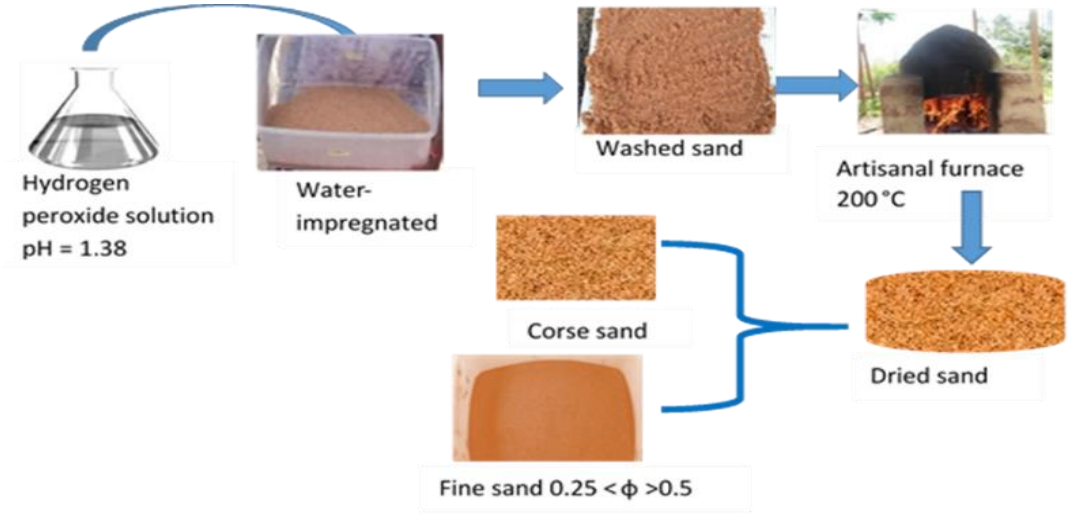


Figure 5: Sand processing

Conduction of experiments

The materials used in this work are sand and coal. Three factors were evaluated. Dirt height, coal height and treated water volume. These are controllable quantitative factors whose range of variation can be extended (Table 2). Prior to testing, a preliminary characterization of the steppe water was carried out. At the end of the tests, the filtered water was also characterized in order to assess the rate of abatement of physical and chemical parameters. The equipment shown in figure 6 is that used to carry out the experiments.

Table 2:
Experimental design

Experiences	Carbon height (cm)	Sand height (cm)	Treated water volume (cm^3)
1	2	6	300
2	6	6	300
3	2	6	1000
4	6	6	1000

The experimental response is the abatement rate for each parameter measured in the raw water and in the treated water. It is given by the following expression

$$T(\%) = \frac{\text{initial value} - \text{final value}}{\text{initial value}} \times 100$$

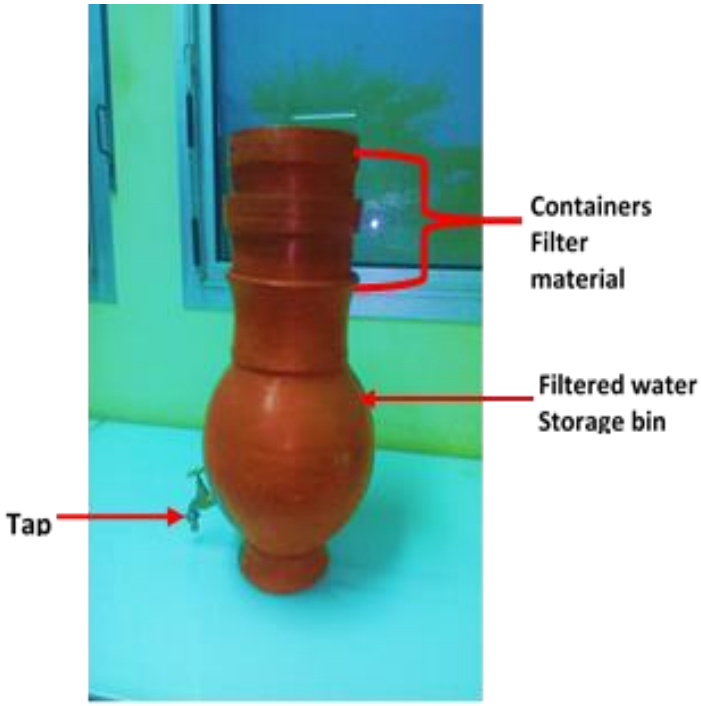


Figure 6: Artisanal water treatment equipment per family u

3. Result And Discussion

3.1. Precursor selection

Specific surface area is of paramount importance in assessing the quality of activated carbons. For this reason [7] consider that a quality activated carbon should have a specific surface area of between 500 and 1500 m2/g. Thus, with regard to specific surface areas of 600 and 250 m2/g. Also, the SEMs obtained show that the activated carbon obtained from roast tree branches is more porous than that obtained from cassava skins.

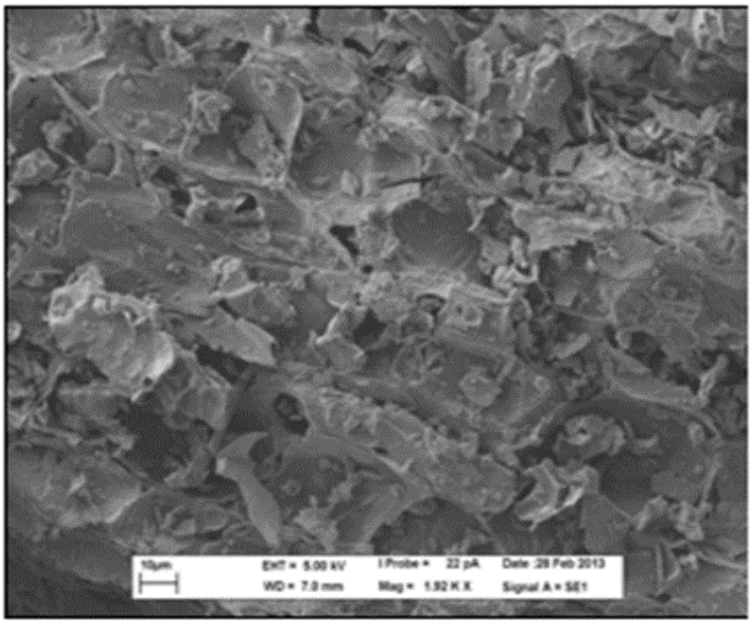


Figure 7: SEM of activated carbon from cassava skins (A)

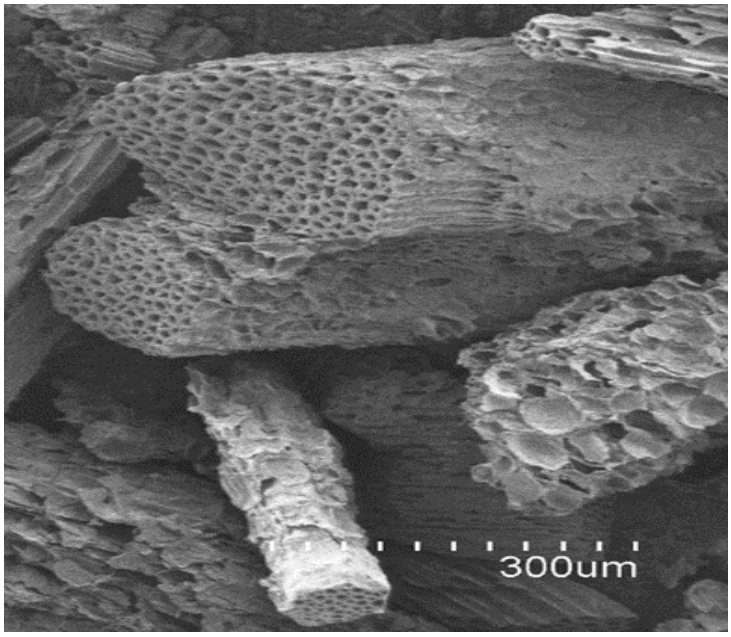


Figure 7: SEM of activated carbon from *BorassusAethiopum* (B)

Elemental analysis of CA-BA was carried out, taking into account carbon, nitrogen, hydrogen and oxygen (Table 3) [8]. This analysis reveals that coal consists of 71 % carbon, 3.42 % hydrogen 0.82 % nitrogen and 24.76 % oxygen. The carbon percentage obtained shows that roast wood is rich in lignite and suitable for the production of quality activated carbon [9]. This carbon percentage falls within the range [50; 90] % recognized by [10,11] as a means of judging the quality of a plant to produce activated carbon. Moreover, this percentage is well above those found by [8] which are 33.48 % and 37.43 % respectively for peanut shells and coconut shells. *Borassusaethiopum* branches are therefore suitable for the production of high-quality activated carbon.

Table 3:
Elemental composition of activated carbon

Elements	***Teneur (%)***
N	0.82
C	71
H	3.42
O	24.76

3.2. Removal of copper from activated carbon

As the activated carbon produced is intended for the treatment of drinking water, it was necessary to eliminate copper ions at the risk of impacting the quality of the filtered water. Copper is an important metal for human life, especially in the formation of tissue in children at low levels [12]. Its evaluation in wash and rinse water is initiated by the presence of copper ions in the copper sulfate solution used to impregnate the carbon (Figure 8). Figure 8 shows that hot washing is effective in removing residual copper ions. In fact, from the first wash to the fifth wash, the average copper ion concentration in the wash water fell from 26.72 mg/L to 0.24 mg/L. As the value of 0.24 mg/L obtained at the end of the wash was higher than 900 µg/day, which is the limit value required for an individual aged 19-70[12], rinsing was necessary.

A single rinse was sufficient to reduce copper ions to 0.01 mg/L. However, this value was still higher than required. A second rinse was then necessary to reduce copper ions below the detection limit of 5 µg [13].

As a result, zero concentration values are recorded from the second rinse onwards. This elimination of copper ions by washing corroborates the study by [14], who were able to eliminate 6.5% of zinc ions by washing alone.

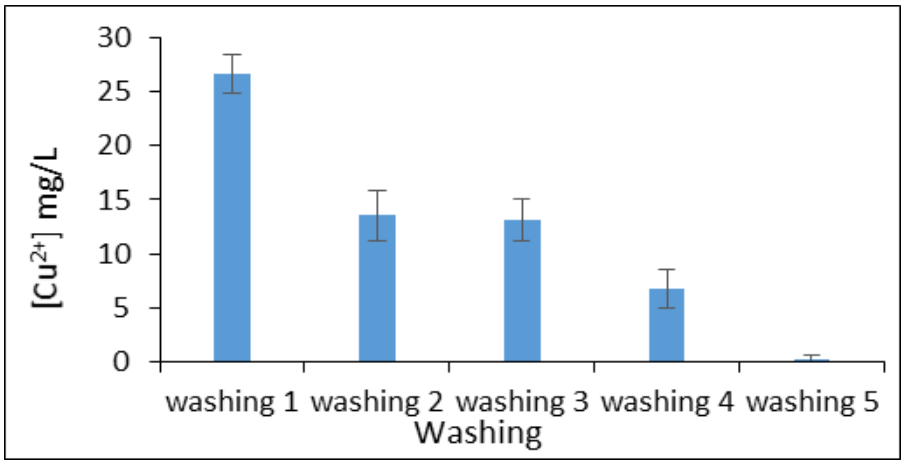


Figure 8: Changes in copper ion concentration during coal washing

3.3. Physical and chemical quality of treated water as a function of activated carbon height

The height of the carbon in the filter and the quantity of raw water treated play a decisive role in the potabilization of raw water. After varying the height and quantity of filtered water, the chemical and physical characteristics of this water are recorded in Tables 4 taking into account the type of activation applied to the carbon. The raw water parameters are listed in the various tables. These tables show that conductivity, turbidity, pH and COD exceed WHO standards.

Table 4:
Raw and filtered water quality

Parameters	Raw water	Unities	Normes OMS
pH	6.25		6 ,5-8,5
Conductivity	175.7	(µS/cm)	200-1000
Turbidity	12.5	(NTU)	< 1
TDS	87.8	(ppm)	1000
NaCl	0.4	(%)	-
Phosphore	0.08	(mg/L)	2
Sulfates	15.56	(mg/L)	500
TAC	1.6	(mg/L)	
Dureté	0.27	(°F)	200 ppm
DCO	33.5	(mgO_2/L)	30
Chlorures	7.1	(mg/L)	200

Figure 9 shows a decrease in COD concentrations in the filtered water, regardless of the experiment considered. Abatement rates of 57.61, 87.46, 51.04 and 74.32 are obtained with experiments 2, 4, 1

and 3 respectively. Across all experiments, the best abatement rates were obtained with charcoal impregnated and then baked before hot washing (CAF). The same is true for pH (Figure 10). pH is improved by the experiment applied with activated carbon (CAF). However, the lowest abatement rates are obtained with the impregnated and simply hot-washed carbon. This could be explained by the low level of carbon activation. Indeed, chemical activation requires a temperature rise to at least 450°C [18,19] . As for physically activated carbon, the average abatement rates observed would be linked to partial carbon activation. According to the authors [18], the activation temperature should be between 900 and 1000 °C. However, in our case study, rudimentary means were used, with a maximum temperature of 100 °C. Conductivity is one of the parameters that highlights the mineralogy of the water. As lake water is moderately mineralized, it cannot be consumed without prior treatment. Unfortunately, regardless of the type of carbon and the arrangement of the filter layers used during the experiment, conductivity has just been improved, but does not comply with the WHO standard. However, in view of the values obtained with CAF activated carbon, good conductivity could be obtained by acting on the activated carbon layer in the filter. Once again, the turbidity value obtained (Figure 9B) demonstrates the effectiveness of CAF carbon. The reduction in turbidity to well below the maximum limit set by the WHO shows that microorganisms are also eliminated during treatment. In fact, turbidity below 0.3 NTU indicates good elimination of certain bacteria such as protozoa [22,23]

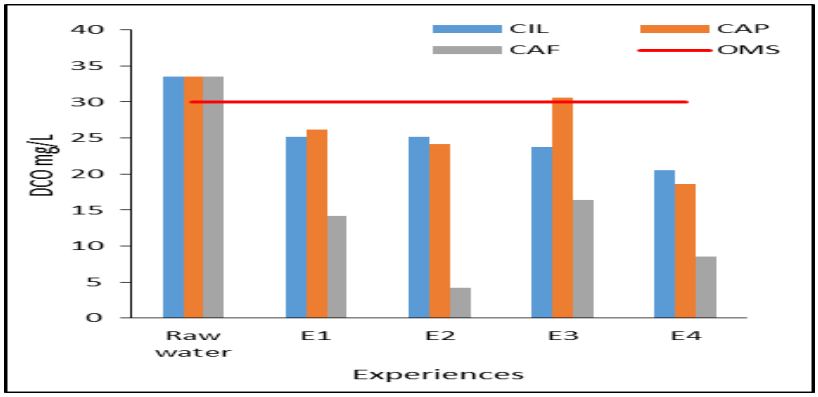


Figure 9: Evaluation of COD (A)

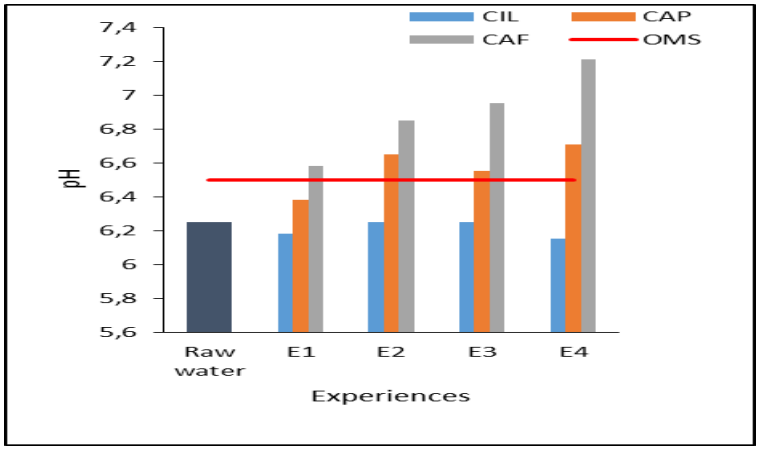


Figure 9: Evaluation of pH (B) during experiments

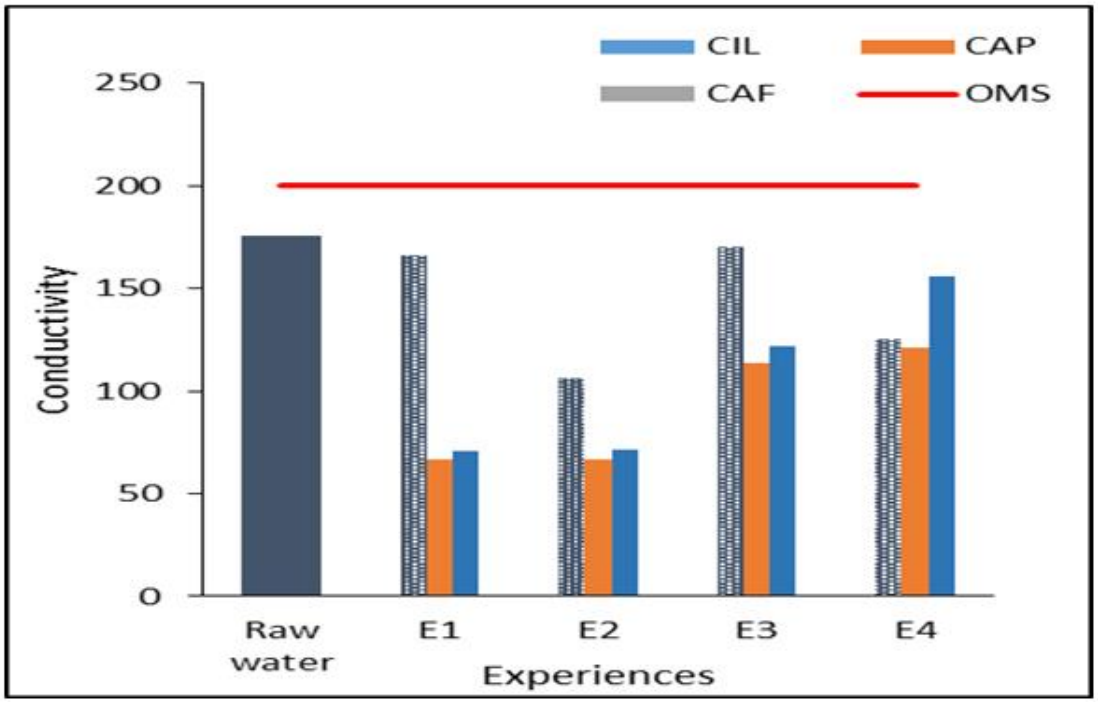


Figure 10: Evaluation of turbidity (B) as a function of experiments

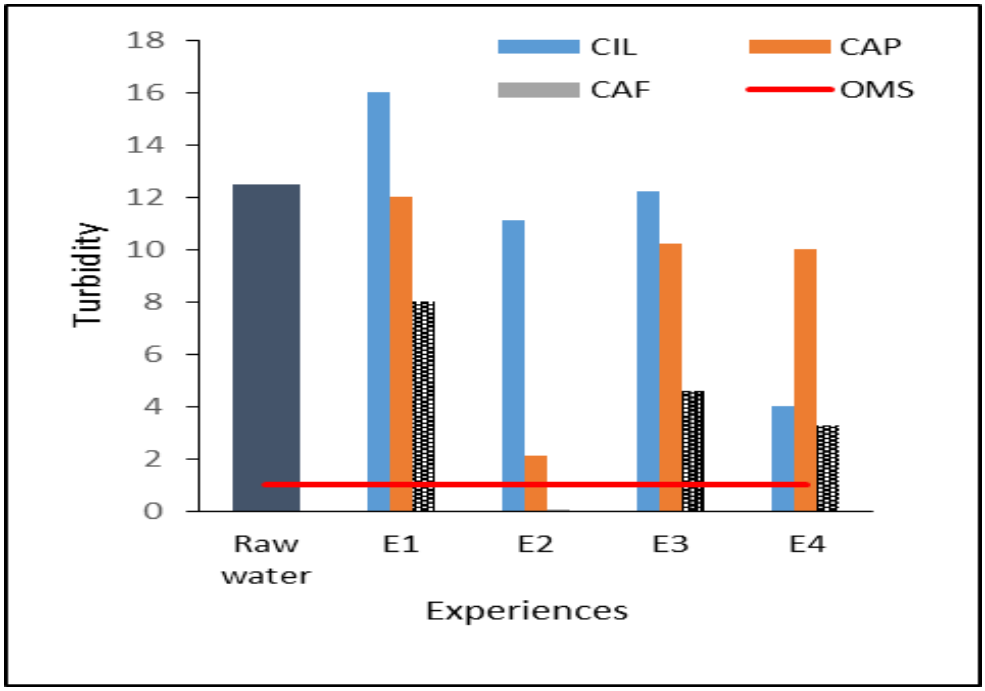
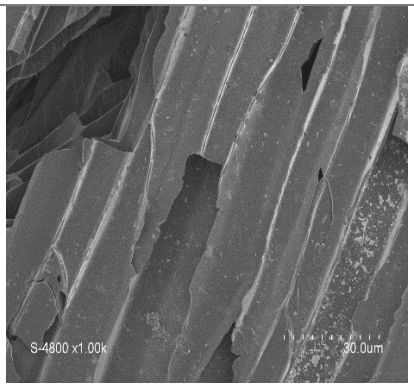
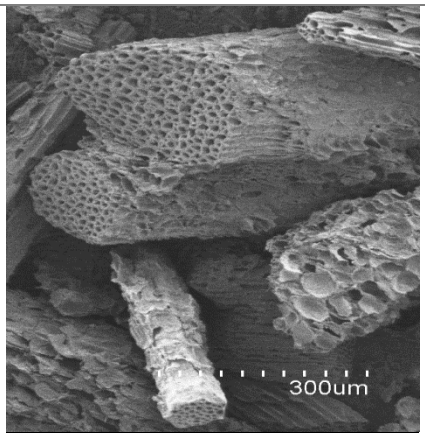
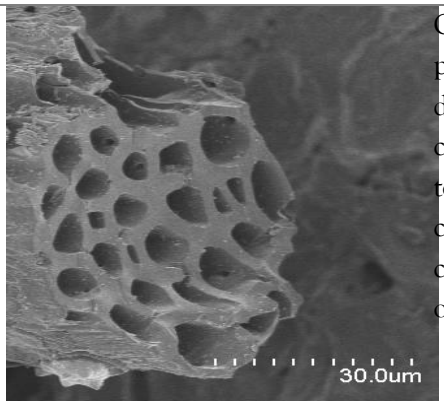


Figure 10: Evaluation of conductivity (A)

3.4. SEM of different activated carbons from Borassusaethiopum

Table 5:
Comparison of different SEMs of activated carbons

Activation type	MEB	Observation
Chemically impregnated and hot-washed coal		The pores are rudimentary and invisible despite an enlargement of 30 µm. The charcoal pores are not developed. Compared to Garba et al. (2014), such a charcoal is only partially activated or not activated at all. The absence of pores could be linked to pore obstruction by the chemical or insufficient water vapor capable of eliciting pore opening.
Physicallyactivatedcarbon		Physically activated carbon has a morphological appearance rich in pores of varying sizes. As the boiling temperature is lower than that recommended by Bamba et al (2009) , which is 650°C and 900°C, this could be responsible for the reduced pore size observed on the surface of the charcoal. Indeed, physical activation by steam is supposed to create larger pores (Molina-Sabio et al. 1996; Bamba et al. 2009).

Chemically impregnated coal baked at 400°C then hot-washed		Chemically activated carbon has a variety of pores on its surface. These pores are more developed than those of physically activated carbon. This is because the rise in temperature to 400°C after impregnation has allowed the copper sulfate particles embedded in the charcoal to expand. As they expand, the pores open up further (Koné et al., 2023).

4. CONCLUSION

Activated carbon is a solution to the problem of insufficient drinking water access. It can be produced by hand using an artisanal furnace. Turbidity results as an indicator of the presence of microorganisms indicate that CAF activated carbon is the one to use. For this, impregnated charcoal needs to spend time in the kiln at a temperature of around 450°C to allow the pores to open. Physical activation in a rural environment is possible if the activation tool is improved so that no water vapor escapes.

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