STUDY OF SOME PHYSICO-CHEMICAL PARAMETERS OF WATER TREATED BY ACTIVATED CARBON BASED ON RONIER FIBRE

Asbtract

Like countries concerned about the health of their population, Côte d'Ivoire is carrying out numerous actions against waterborne diseases through the treatment of drinking water. In this study, we collected water samples from three sites on which we carried out in situ analyses as well as laboratory analyses. The results generally showed that the parameters studied comply with the chosen standard, except for nitrites and nitrates; COD and iron content. The samples were treated on a filter consisting of a layer of activated carbon from palmyra fiber topped with a quantity of sand, all in a 4.6 cm diameter column. Analysis of the filtrates showed reduction rates ranging from 19.5% to 76.6% for in situ parameters, 23.8% to 92.8% for nutrients. The reduction rates for suspended solids and COD are around 100%. These are fresh waters with a corrosive character, with a strong correlation between the parameters studied.

Key words: Activated carbon, palmyra fiber, filter, Ryznar index, correlation circle

INTRODUCTION

Source of life, water is probably the most important of all natural resources. It is vital for living organisms, large ecosystems and human health **[1]**.Faced with waste, prolonged droughts, and poor management of available water resources, water shortages are beginning to be felt on all continents. In Africa, particularly in West Africa, this lack of water is felt in both urban and rural areas **[2]**. In Côte d'Ivoire, access to drinking water in rural areas is very difficult due to the lack of a water treatment system **[3]**. Populations use water from backwaters, wells or other sources for consumption **[4]**. They are therefore subject to various waterborne diseases, especially for children. It is therefore urgent to find solutions to improve the quality of the water consumed by these populations. Several methods of treating these waters are available. But in order to enhance the value of natural resources, we are conducting investigations to provide good quality water to populations. Activated carbon is an essential palliative to provide good quality water **[5-6]**. Among these natural resources, we have the palmyra palm, which is a very widespread plant in central Côte d'Ivoire. Its nut is highly prized and the branches are very rarely used as fuel for cooking. The objective of this study is to prepare activated carbon based on palmyra palm fiber in order to treat water for consumption.

MATERIALS AND METHODS

1. Sampling

The sampling took place in two stages. A first stage which consisted of the collection of plant material (palmyra branch) for the production of activated carbon and a second stage which consisted of the collection of water samples (river, lake, and well) for analysis.

2. Activated carbon

2-1. Preparation

The collected palmyra branches are cut into small pieces then washed with water and dried in the sun for 1 week. The preparation of the carbon was carried out according to the method used by **Zran and al. (2022)[7]**. After drying, they are impregnated in a 2 M orthophosphoric acid solution for 24 h. They are finally calcined at 500 °C for 5 h in an OBERSAL oven. The sample is then removed from the oven and placed in the desiccator for cooling. Once cooled, the carbon is then crushed and rinsed several times with distilled water until a pH of between 6 and 7 is obtained. Finally, the wet samples are dried in an oven at 150°C for 24 hours and stored in hermetically sealed bottles previously labeled.

2-2. Characterization of prepared activated carbon

The physicochemical characteristics of prepared activated carbon were determined according to the conventional methods used by **Aboua (2013)[8]**. These are the mass loss, the ash rate, the iodine index, the specific surface and the surface functions.

3. Obtaining sand

The sand used for the different filtrations was collected at the seaside and underwent the following different treatments: wash with tap water until obtaining clean rinsing water, the sand was put in an oven at 105 ° C for 24 hours. It was then sieved to use the desired particle size.

4. Filtration of different samples

The filter consists of a cylindrical column with an internal diameter of 4.3 cm in which a mass of 2 g of carbon is placed between two layers of 25 g of sand each according to Figure 1.A quantity of 400 mL of water of different origin is filtered and certain physicochemical parameters of drinking water were determined.

Figure 1 : Filtration device

RESULTS AND DISCUSSION

1. Characterization of the prepared activated carbon

The carbon obtained has a specific surface area of 578.2 $m^2.g^{-1}$. This value is lower than that found by **Abo and al (2021**)**[9]** for activated carbon based on corn cobs. In fact, it obtained a specific surface area of 673.8 $m^2.g^{-1}$**[8]**. The iodine index which provides an indication of the microporosity of the activated carbon gave a value of 168.31 $mg.g^{-1}$. This value is low compared to that obtained by **Afrane and Achaw in 2008[10]**). Indeed, the latter obtained iodine number values ranging from 250 $mg.g^{-1}$ to 640 mg/g from activated carbons prepared with coconut shell **[10]**. This carbon is nevertheless suitable for water treatment tests.

2. Characterization of the sampled waters

Table 1 presents the physicochemical characteristics of the well, lake and river waters. The values obtained are compared to the standard of Decree 2001-1220 of December 20, 2001 relating to water intended for human consumption, excluding natural mineral waters.

The temperature values vary from 27 °C to 30 °C from the well to the river. The well water is slightly cold due to the depth. It therefore does not receive sunlight. The values of 29 °C and 30 °C obtained, respectively, for the lake and the river are due to the effect of sunshine. These values are similar to those obtained by **Odjohou and al. (2020**)**[11]** on Lake Labion. Indeed, surface waters in humid tropical areas are around 30°C **[12]**.

The pH values obtained comply with the standard given by Decree 2001-1220 of December 20, 2001. They are also similar to the values obtained by **Odjohou and al. (2020)[11].**

Electrical conductivity varies from 79 µS/cm for lake water to 319 µS/cm for well water. This shows that the waters are moderately mineralized and therefore do not contain enough dissolved mineral salts. These electrical conductivity values are higher than the results of the work of **Odjohou and al. (2020**)**[11]**.

TDS measures the quantity of organic and inorganic ions dissolved in water. It varies according to the salinity of the water according to the standards below:

- Fresh water (<1000 ppm TDS);
- Brackish water (slightly salty) (1000 to 10000 ppm TDS);
- Salt water (10000 to 30000 ppm TDS);
- Brine water (very salty) (>30000 ppm TDS)

According to **Tfeil and al., in (2018**)**[13]**, the standard for fresh drinking water is <400ppm TDS. The values obtained fit perfectly into the standards for fresh water (<1000 ppm TDS).

In general, the values obtained meet the standard, except for the nitrate and nitrite contents for well water, and the chemical oxygen demand (COD) values for the three sources. The high nitrate content in the well could be explained by the fact that nitrogen is originally fixed from the atmosphere and then mineralized by soil bacteria into ammonium. Under aerobic conditions, nitrogen is eventually converted to nitrate by nitrifying bacteria**[14]**. These results are similar to those of the work of **Lagnika and al. (2014)[15]**. The COD measurement corresponds to an estimate of the oxidizable materials present in the water, regardless of their organic or mineral origin. Around the lake and the river, which are surface waters, these values could be reflected by the anthropogenic activities taking place in the vicinity of these bodies of water **[16]**. The COD of well water could be explained by the infiltration of wastewater into the well **[15]**.

The study of the calco-carbonic balances calculated according to the simplified version of the modified Hallopeau-Bubin method (1.5) showed that the waters of the well, the lake and the river have a clear tendency to corrosion.

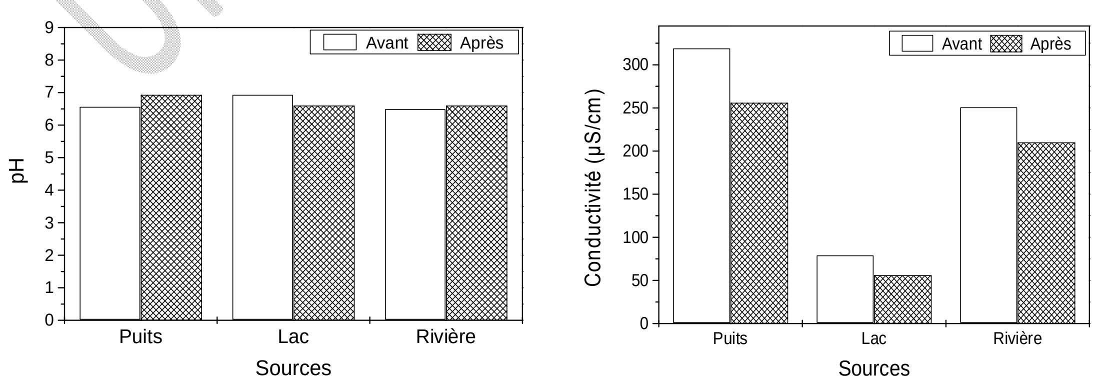
Table 1: Physicochemical characteristics of water samples

Parameters	Well water	Lake water	River water	**Decret 2001- 1220 of 20/12/ 2001**
Temperature	27	29	30	25
pH	6,6	6,9	6,5	6,5 – 8,5
Conductivity(µS.cm^{-1})	319	79	250	200-1000
TDS (ppm)	161	40	126	-
Turbidity (NTU)	13	14	41	2
MES (mg.L^{-1})	10	60	20	25
Phosphates (mg.L^{-1})	0,11	0,10	0,06	0,4
Sulfates (mg.L^{-1})	46,21	16,54	28,60	250
Ammonium (mg.L^{-1})	0,48	0,21	0,49	1,5
Chlorures (mg.L^{-1})	42,60	49,70	60,35	250
Nitrates (mg.L^{-1})	650	40,54	49,35	50
Nitrites (mg.L^{-1})	46	2,86	3,77	3
COD (mg.L^{-1})	96	518	261	30
Ca^{2+}(mg.L^{-1})	34,34	54,22	3,87	-
Mg^{2+}(mg.L^{-1})	10,71	21,59	20,62	-
Mn^{2+}(mg.L^{-1})	0,04	0,07	0,02	0,05
Fe^{2+}(mg.L^{-1})	0,6	3,3	4,8	0,2

3. Water treatment with the carbon and sand filter

3.1. Evolution of in situ parameters

The evolution of in situ parameters during filtration is shown in Figure 2. Filtration has no real impact on pH but it reduces conductivity, TDS and turbidity. Indeed, for well water, we obtain a decrease in conductivity of 19.5%, TDS of 88.6% and turbidity of 98.2%. As for lake water, conductivity decreases by 29.1%, TDS by 71.7% and turbidity by 54.4%. Filtration of river water results in a decrease in conductivity of 16.2%, TDS of 67.2% and turbidity of 76.6%. The filter therefore reduces TDS and turbidity by more than 50%. So we have fresh water for all three sources, with the well water and river water being moderately mineralized while the lake water becomes weakly mineralized.



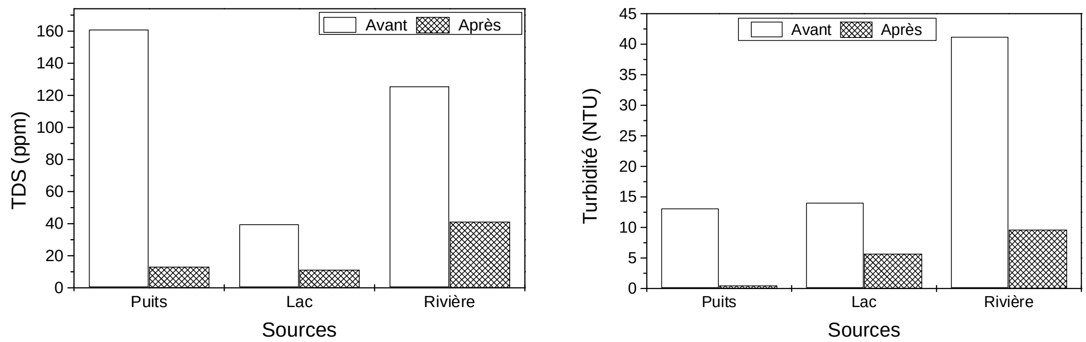
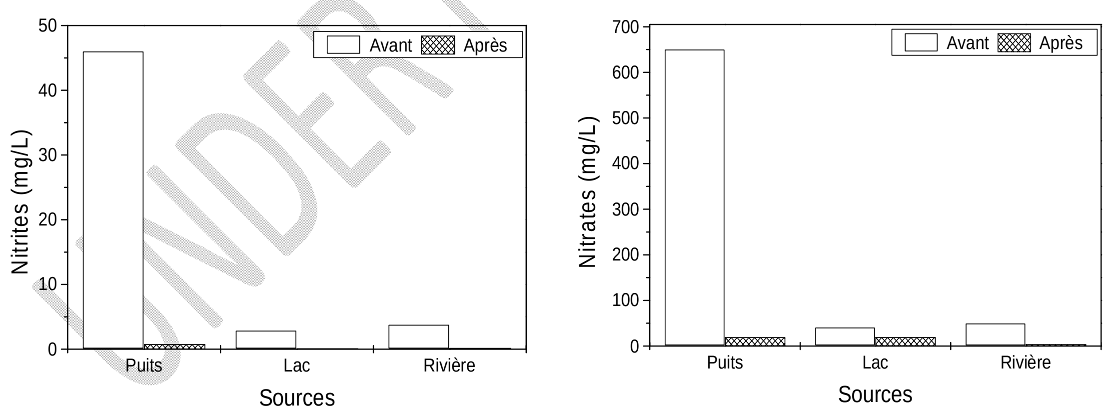


Figure 2 : Variation of in situ parameters after filtration

3.2. Evolution of nutrients

The evolution of nutrients after filtration is shown in Figure 3.The filtration of water taken from the well, lake and river leads to an increase in the phosphate content. Indeed, the carbon used for this filtration was activated by ortho-phosphoric acid. Therefore, a certain amount of phosphate is released into the water without this being detrimental to consumption. Because the final contents are less than 0.4 mg/L; the limit content given by the decree. However, a decrease in nitrate, nitrite and ammonium contents is observed. For well water, the nitrate content decreases by 97%, that of nitrites by 98.7% and that of ammonium by 60.4%. For lake water, the nitrate content decreases by 51.7%, nitrites by 98.4% and ammonium by 23.8%. The filtration of the river water has allowed to have a reduction of nitrates of 91.9%, nitrites of 92.8% and ammonium of 61.2%. This treatment allows to obtain nitrate contents below the standard imposed by the decree 2001-1220 of December 20, 2001. Indeed, the nitrate contents are of the order of 19 mg/L for the well and the lake, while it is 4 mg/L for the river.



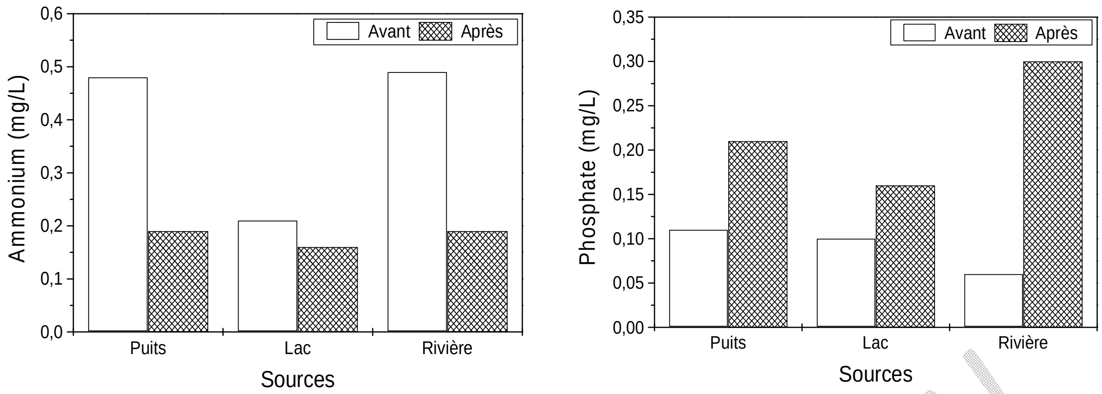
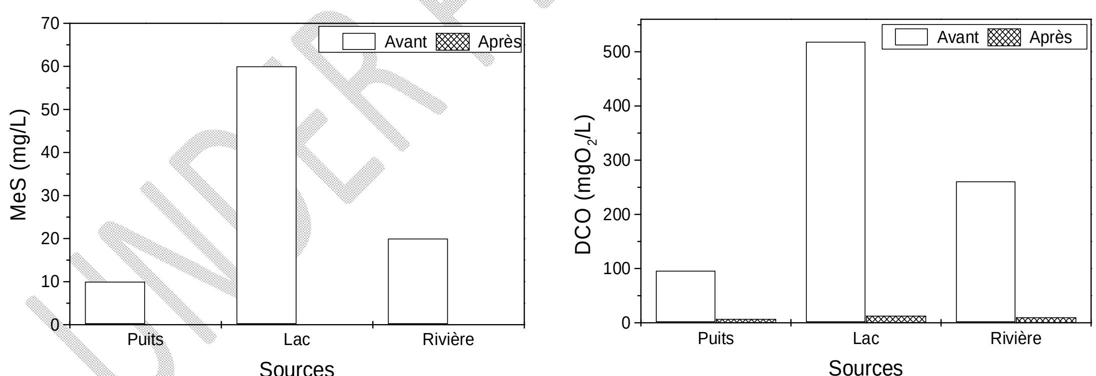


Figure 3: Variation in nutrients after filtration

3.2. Evolution of the COD, the MES, sulfates and chlorides

We also followed the evolution of the contents in COD, suspended matter, sulfates and chlorides. The results are presented in Figure 4.The rate of elimination of sulfate and chloride ions depends on the source. While sulfates are better reduced in well water (37.5%), the best rates for chloride ions (64.7%) are obtained in river water. As for the elimination of COD and MES, the rates are of the order of 96% and 100%, respectively. The results are similar to the work of **Dumoutier and al. (1992)[17].**



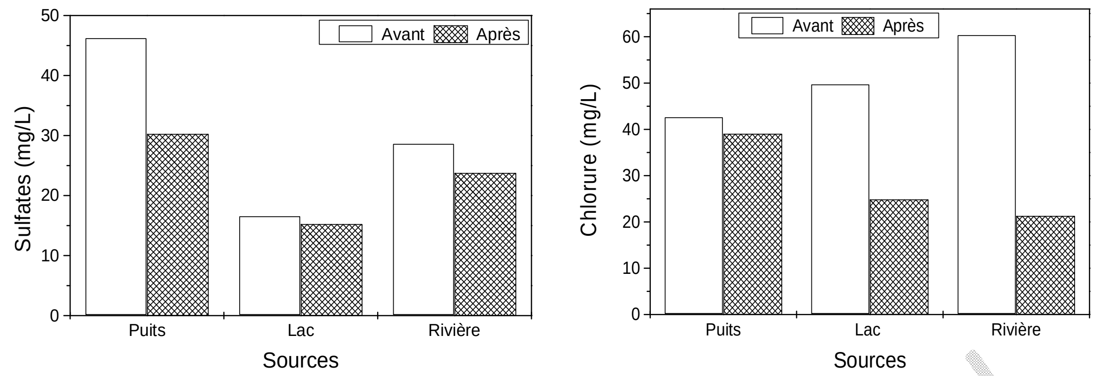


Figure 4: Variation of organic parameters after filtration

4. Study of water stability

In order to study, and especially to predict the behavior of our filtrates, we will calculate the saturation pH (pHs) which is the pH value corresponding to a perfect physicochemical equilibrium of calcium bicarbonates in solution, therefore to the disappearance of any encrusting or aggressive tendency of the water. The PHs is given by the Langelier formula modified and simplified by Larson and Buswell as follows:

$$pH_s = 9{,}3 + A + B - (C - D)$$

où :

A = Facteur de T.D.S (totalité des sels dissous)
B = Facteur de température
C = facteur de dureté du calcium exprimé en °f
D = Facteur d'alcalinité totale (au méthylorange) TAC exprimé en °f.

The value of 〖pH〗_s is 9.3. The comparison between the 〖pH〗_s and the actual pH of the water allows us to establish a so-called saturation index such as: $I = pH_{réel} - pH_s$

So :

$$I = -2{,}8 \; for\ well\ water$$
$$I = -3{,}1 \; for\ lake\ and\ river\ waters$$

Since these values are negative, our filtrates have a tendency to corrosion. In order to obtain more precise and reliable indications, a different notation, called the Ryznar index, is increasingly used:

$$IR = 2pH_s - pH_{real}$$

That is:

$$IR = 12{,}5 \; for\ well\ water$$
$$IR = 12{,}8 \; for\ lake\ and\ river\ waters$$

IR>8.7 in all cases, we have confirmation that our filtrates are aggressive. This is further confirmed by the simplified version of the modified Hallopeau-Bubin method (1.5) which shows that the waters of the well, the lake and the river have a clear tendency to corrosion.

5. Statistical study of some physical and chemical parameters of water

The table of eigenvalues indicates that only factors 1 and 2 with respective eigenvalues of 4.693 and 4.048 are representative. Indeed, according to **Koné and al, (2022)*[18]*** a factor is representative when its eigenvalue is greater than or equal to 1.

Principal component analysis on all well, lake and river water data reveals strong correlations between the different parameters. For this study, the correlation is significant when the correlation coefficient R ≥ 0.70 as Koné **and al, (2022)*[18]***. It is clear from the correlation matrix and the correlation circle Figure 5 that calcium and manganese with respective correlations of 0.80 and 0.7 influence conductivity. On the other hand, TDS are impacted by sulfates and ammonium which have respective correlations of 0.93 and 0.90. Also, temperature has a significant impact on chlorides and magnesium. Indeed, with respective correlations of 0.80 and 0.85, chlorides and magnesium can experience changes in water for high temperatures.

Table 2: Choice of factors

Eigenvalues(correlation matrix.) &associated statistics (Datasheet 1) Active variables only				
	Eigenvalues	**% Total**	**Cumul**	**Cumul**
1	4.693294	46.93294	4.69329	46.9329
2	4.048683	40.48683	8.74198	87.4198
3	0.965388	9.65388	9.70736	97.0736

Table 3: Correlation matrix

Significant correlations marked at p <0,05000										
	T °C	**Cond ($\mu S.cm^{-1}$)**	**TDS (ppm)**	**SO_4^{3-} ($mg.L^{-1}$)**	**$NH4^+$ ($mg.L^{-1}$)**	**Cl^- (mg.L-1)**	**Ca^{2+} ($mg.L^{-1}$)**	**Mg^{2+} ($mg.L^{-1}$)**	**Mn^{2+} (mg.L-1)**	**Fe^{2+} ($mg.L^{-1}$)**
T °C	1,00									
Cond	**-0,78**	1,00								
TDS	-0,51	0,06	1,00							
SO_4^{3-}	**-0,73**	0,40	**0,93**	1,00						
$NH4^+$	-0,16	-0,33	**0,90**	0,72	1,00					
CL^-	**0,80**	**-0,98**	-0,17	-0,50	0,24	1,00				
Ca^{2+}	-0,35	**0,80**	-0,55	-0,22	**-0,81**	**-0,71**	1,00			
Mg^{2+}	**0,85**	**-0,71**	**-0,73**	-0,91	-0,39	**0,79**	-0,16	1,00		
Mn^{2+}	-0,30	**0,70**	-0,53	-0,24	-0,75	-0,58	**0,89**	-0,08	1,00	
Fe^{2+}	0,07	-0,36	0,05	-0,04	0,28	0,43	-0,29	0,29	-0,13	1,00

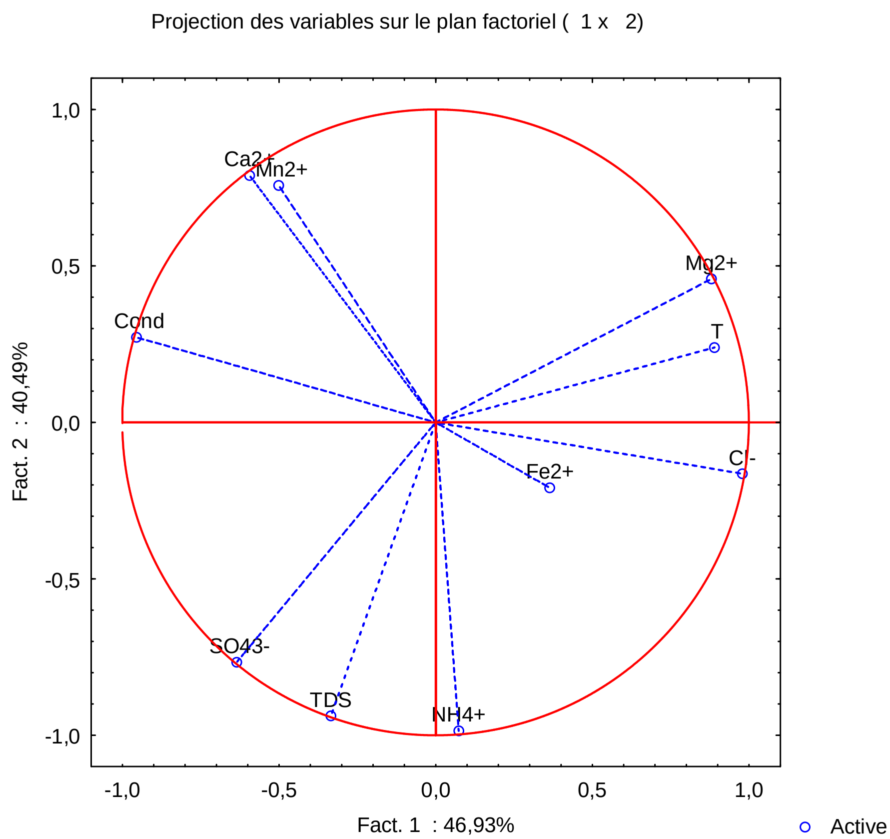


Figure 5 :Correlation circle

CONCLUSION

The study of the physicochemical quality of water treated with activated carbon based on palmyra fiber was the subject of the work presented here. This study has a double interest that are the valorization of palmyra branches and the creation of a prototype of water treatment for populations in rural areas. Indeed, faced with the different problems encountered by populations in rural areas particularly that of drinking water, it was judicious to study the conditions of use of activated carbon based on palmyra fibers for the filtration of surface water. The experiments carried out during the treatment of different samples of surface water, including well, lake, and river water, allowed us to evaluate the effectiveness of our treatment prototype through the calculation of the different reduction rates for each quality parameter selected. The different values of the reduction rate obtained allowed us to conclude on the effectiveness of our prototype.

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Author Contributions

Yobouet Yao Augustin and Djedjoss Essoh Jules-César designed the work and the experiment. Yobouet Yao Augustin and MANOUAN Werdjess Max Robin prepared the materials. ZRAN Vanh Eric-Simon and MANOUAN Werdjess Max Robin wrote the manuscript. TROKOUREY Albert and ZRAN Vanh Eric-Simon revised the manuscript critically. All authors read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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