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Local Biomass Converted into Activated Char for the Treatment of Well Water

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Abstract

The taste and color define the quality of water in Kaolack. This water is compromised by the presence of impurities such as fluoride (1.69 mg/l) and other physicochemical parameters (low electrical conductivity, TDS, pH = 5.1, etc.), which can have negative effects on the health of residents and food safety. This work explores an innovative solution involving the use of two reservoirs (fired clay and plastic) of activated carbon produced from ditakh (*Detarium senegalense*), a local fruit with exceptional properties (calorific value of 19.13 MJ/kg for the raw shell and a calorific value of 28.22 MJ/kg obtained after pyrolysis of the shell), to improve water treatment. The main objective is to evaluate the effectiveness of this natural material (activated and non-activated char) in removing questionable contaminants from water. The results obtained show that activated char based on ditakh exhibits a slight increase in initial electrical conductivity and a shift in pH from acidic to alkaline. It is noted that ditakh shell char activated in a fired clay reservoir has a more effective adsorption capacity compared to other types of char (non-activated wood char, referred to as CNB, and non-activated ditakh shell char, also referred to as CNA, under the same conditions). The results also show that the best amount of char to treat this water, in a quantity of 200 g, is between 0.5 and 1 g.

Keywords

Physical Char Activation Using Water Vapor, Activated Char from Ziguinchor Ditakh Shells, Treatment of Well Water Using Activated Char, Use of Canaries for Water Conservation

1. Introduction

In Senegal, although several rivers and lakes cross the country, groundwater has always been an essential source of drinking water. However, although this water has been purified of many impurities [1], it contains substances that, when they exceed a certain concentration threshold, can significantly compromise the potability of the water [2]. However, in the city of Kaolack, this water is of poor quality due to its proximity to the sea, which makes it unfit for consumption with an abnormally high fluoride level of 3.5 mg/l. In addition, certain physicochemical parameters exceed the drinking water standards recommended by the OMS to remedy this problem, several water treatment methods have been presented in the literature. Authors such as Drissa Bamba *et al.* [3] used chemical membranes to treat water and concluded that these membranes significantly reduced contaminant concentrations (sulfates, fluoride, manganese, etc.) while improving water potability. However, these membrane filters have limitations related to processes, equipment, contaminants, and water quality. In rural practice, however, water is stored in a canari, which remains without scientific explanation but is still an effective technique for water treatment. This is because terracotta and ceramics are known for their thermoregulatory role and, due to their porous nature, naturally purify water through filtration, remineralization, and the elimination of impurities. It is therefore necessary to explore the types of filters that can be used in Africa. One promising solution lies in the use of ditakh shells (*Detarium senegalense*) for the production of activated carbon. With this in mind, it is essential to clearly define the objectives in order to better guide our approach and optimize the expected results.

The main objective of this study is to evaluate the effectiveness of activated carbon produced from ditakh shells (*Detarium senegalense*) in treating contaminated water. To achieve this main objective, the study has three specific objectives:

- First, to analyze the adsorption capacity of activated carbon for various contaminants present in water;
- Next, to compare the performance of activated carbon from ditakh shells with other types of carbon (non-activated ditakh carbon, char);
- Finally, to propose concrete recommendations for the optimal use of activated carbon in the treatment of well water in Kaolack, taking into account local specificities.

2. Materials and Methods

To achieve these objectives, it is essential to clearly define the key steps that will guide our actions and ensure the success of our approach. These steps are divided into four main phases. The exploratory phase, which consists of conducting an initial analysis of the quality of well water in Kaolack and examining the properties of ditakh as a raw material for the manufacture of activated carbon. **Figure 1** can illustrate the storage technique used during the experimental process. This figure shows an image of a plastic tank and a fired clay tank.

Figure 1. Presentation of the two types of tanks used during treatment.

The ditakh shell used is from Ziguinchor. The work on the samples mainly involves the preparation, packaging, and characterization of *Detarium senegalense* "ditakh" nuts, followed by pyrolysis and activation of the char for water treatment.

Table 1. Results of the basic analysis of the shell and image of the ditakh nutditakh.

Ditakh Shells		
Elemental Analysis (dry weight%)		**Nature brute**
Carbon	47.80	
Hydrogen	5.95	
Oxygen	46.08	
Nitrogen	0.16	
Soufre	0.009	
Waste quantity (tones)		
2016	518,968	
2022	801,302	

The first step involves collecting the raw material, then separating the components of the ditakh nut, distinguishing between the different parts such as the shell, the kernel, and/or the almond. The second step involves conducting an in-depth characterization of these shells to determine their elemental composition (**Table 1**). The elemental analysis (carbon, hydrogen, and nitrogen content) of the prepared sample was carried out in a French laboratory, SOCOR, in DECHY. The work was carried out in accordance with standard NF EN ISO 16948 and Internal Method PA 334. The results obtained are listed in **Table 1**.

Washing the sample after harvesting using tap water reduces impurities, and then the ditakh nuts are dried naturally and roasted. In order to separate the shells from the kernels, we proceed to shell the nuts. The shells were shredded, but a small portion was ground for physicochemical characterization and thermogravimetric analysis (TGA). Finally, the activated carbon manufacturing process, which includes essential steps such as washing, drying (105˚C), grinding (1 mm), carbonization at 750˚C, and physical activation, is summarized in **Figure 2**. The atmosphere during activation consists of 4 Nl/min of water vapor (H_2O) diluted in a flow of 5 NL/min of nitrogen.

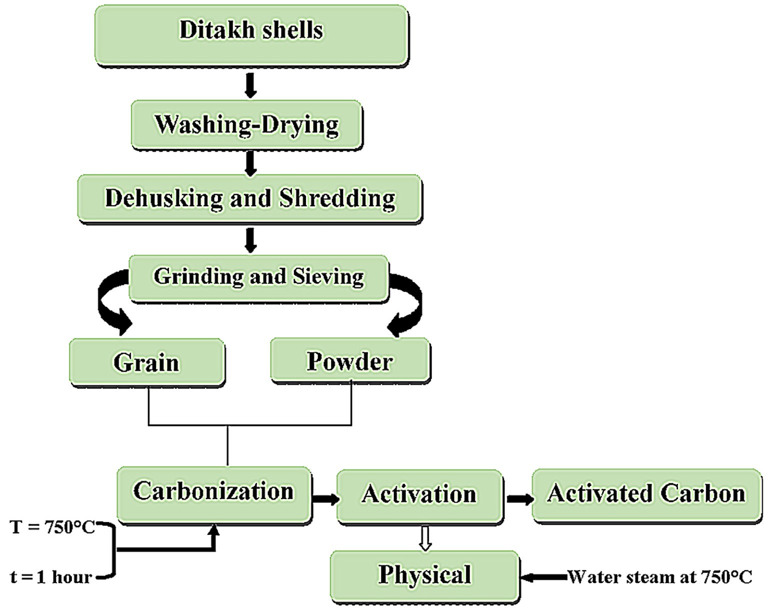

Figure 2. Operating protocol for obtaining CA from ditakh shells.

The ATG profile of ditakh shell degradation over time is illustrated in **Figure 3**. This figure shows the different mass losses of the sample. A mass loss of 1.2% is observed between 15 and 20 minutes. Below this period, the degradation of the shells leads to the release of volatile matter (74.4%), the formation of fixed carbon (20.3%), and ash (4.1%).

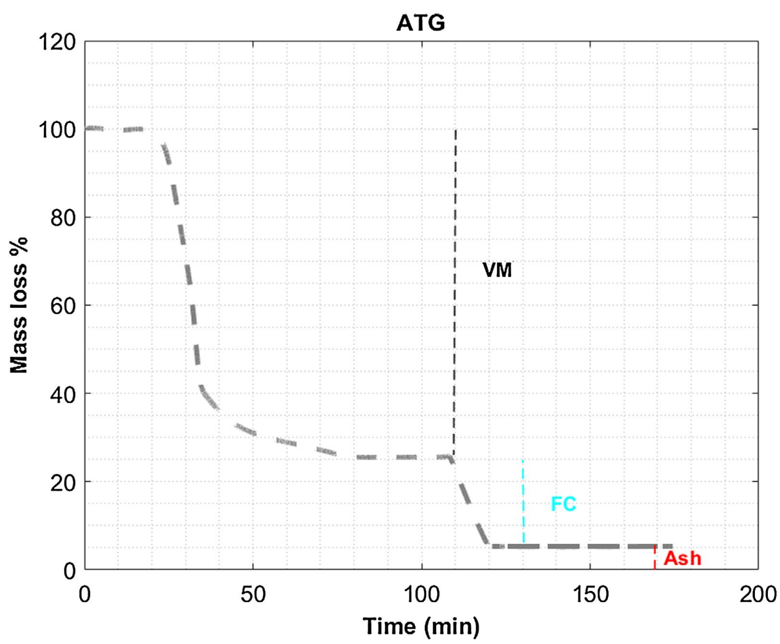

Figure 3. Mass loss curve as a function of time.

The graph of the TGA and TGA curves obtained during pyrolysis shows four distinct peaks (**Figure 4**), representing the degradation phases of the different components of the sample. The first peak, at 99˚C - 100˚C, naturally corresponds to the evaporation of moisture, while the second peak, at 310˚C, corresponds to the degradation of hemicellulose. The third, more intense peak appears at 365˚C and reflects the degradation of cellulose. Finally, lignin decomposes over a wide temperature range, from 440 to 800˚C, the latter representing the upper limit of ditakh shell pyrolysis at a heating rate of 10˚C/min.

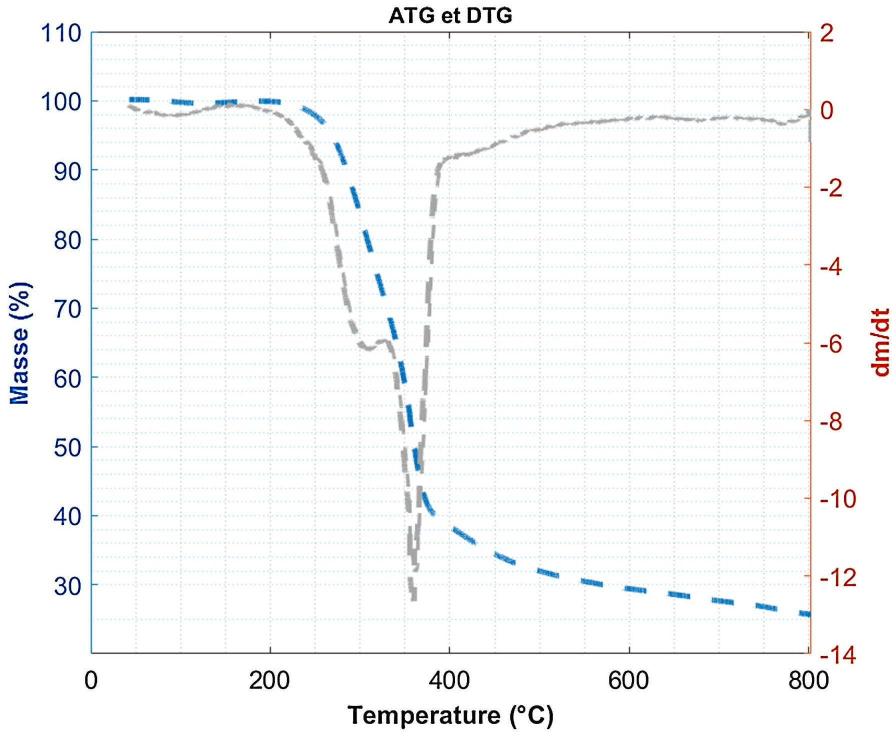

Figure 4. Mass loss curves as a function of time, and the derivative of mass loss with respect to temperature.

In addition, the analysis phase consists of treating the collected well water samples with three types of active or inactive char produced from ditakh and wood, using baked clay or a plastic beaker as a storage container. Water quality parameters such as pH, turbidity, temperature, TDS, and conductivity were measured before and after treatment to evaluate the effectiveness of the process. Thus, before treatment, an analysis was carried out, the information received from the Assane Seck University Laboratory in Ziguinchor was listed in **Table 2**, indicating slightly acidic water, low electrical conductivity, and a very high fluoride level compared to the recommended value.

We therefore found it useful to treat this water with activated or non-activated char from ditakh shells and wood in order to provide a solution for the population of Kaolack.

The results obtained from this treatment are presented in the results and discussions section.

Table 2. Initial parameters of Kaolack well water.

Parameters	Well Water	Measurement Unit	Drinking Water Recommendations
pH	5.10	-	6 = 9
Conductivity	268.00	µS/cm	<1300
Total Hardness	5.00	˚f	-
Turbidity	2.48	NFU	<5
Total Alkalinity (TAC)	4.00	˚f	-
Sulfates	1.00	mg/l	<250
Chlorides	98.10	mg/l	<250
Total Iron	0.09	mg/l	<0.3
Manganese	0.60	mg/l	<0.4
Fluoride	1.69	mg/l	<1.5
Nitrites	0.31	mg/l	<3
Ammonium	0.09	mg/l	<0.5

3. Results and Discussions

In order to achieve optimal experimental conditions, the work was carried out on a water mass of 200 g, combined with several quantities (0.1 to 8 g) of activated char, all stored either in a plastic beaker or a cooked beetle cage during the treatment period. We are now analyzing the effect of the amount of char on the physical parameters of the water, such as electrical conductivity (EC), pH, total dissolved solids (TDS), and temperature.

3.1. Effect of the Amount of Char and the Type of Water Storage Tank on the Physicochemical Parameters of Water

3.1.1. The Electrical Conductivity

The electrical conductivity of water is a measure of a solution's ability to conduct electrical current through it and depends on the concentration of mineralization and ionic charge. Electrical conductivity is used to indicate mineral constituents that are fully ionized in water [4]. However, as shown in **Figure 5**, adding between 0 and 2 g of activated char to the water increases the electrical conductivity from an initial value of 260 to 600 µS/cm, which is still within the WHO recommended values (<1300 µS/cm). This low conductivity indicates low mineralization of the water. Activated char effectively adsorbs impurities without releasing minerals.

However, above 2 g of char, we see a rapid increase in conductivity, which could be due to the probable remineralization of the water by this activated char. We also note greater stability in the electrical conductivity results obtained from water stored in a fired clay pot. This effect of clay on treatment is rarely mentioned in the literature, but authors such as [5] and [6] have reported the positive effect of clay on water treatment.

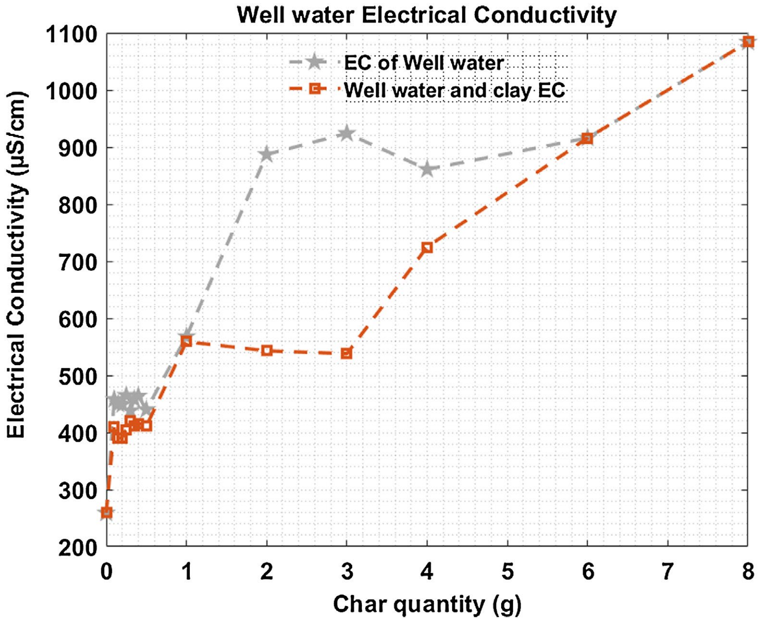

Figure 5. Change in the electrical conductivity of well water as a function of the amount of ditakh char.

3.1.2. The pH of Water

The pH tells us about the acidity or alkalinity of the environment. The WHO acceptable value for drinking water is between 6 and 9. Below the minimum value, water has a bitter, metallic taste and can corrode equipment. Above the maximum value, undesirable effects include a slippery sensation, a soda-like taste, and the presence of deposits [1]. **Figure 6** shows an increase with the addition of char, with or without clay. For char quantities between 0 and 2 g, the pH varies gradually

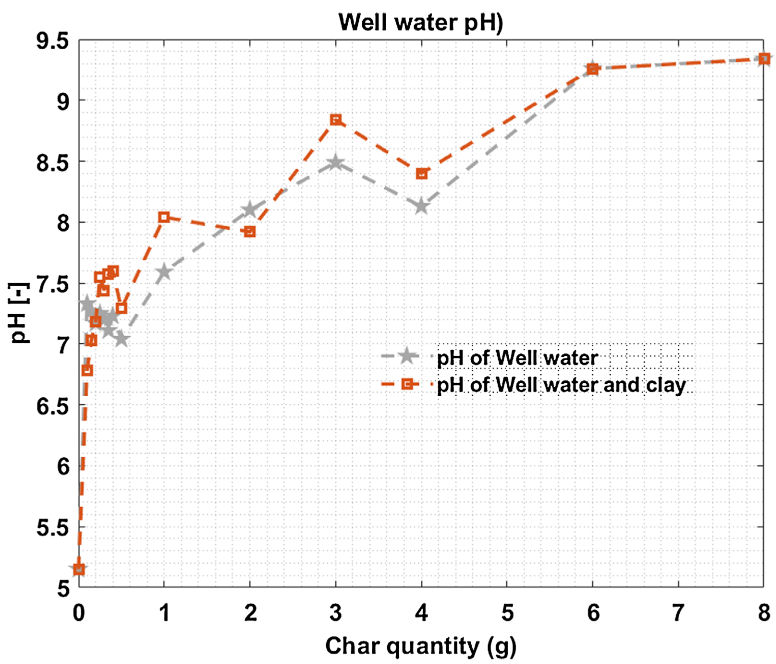

Figure 6. Change in well water pH based on the amount of ditakh char.

between 6 and 8, complying with OMS standards for drinking water (pH between 6 and 9).

This indicates good water quality. Clay stabilizes the pH and improves the adsorption of impurities. Above 2 g of char, the pH increases significantly, which is not desirable for consumption.

3.1.3. The Water Temperature

Water temperature is an important factor in determining whether a body of water is suitable for human consumption and use.

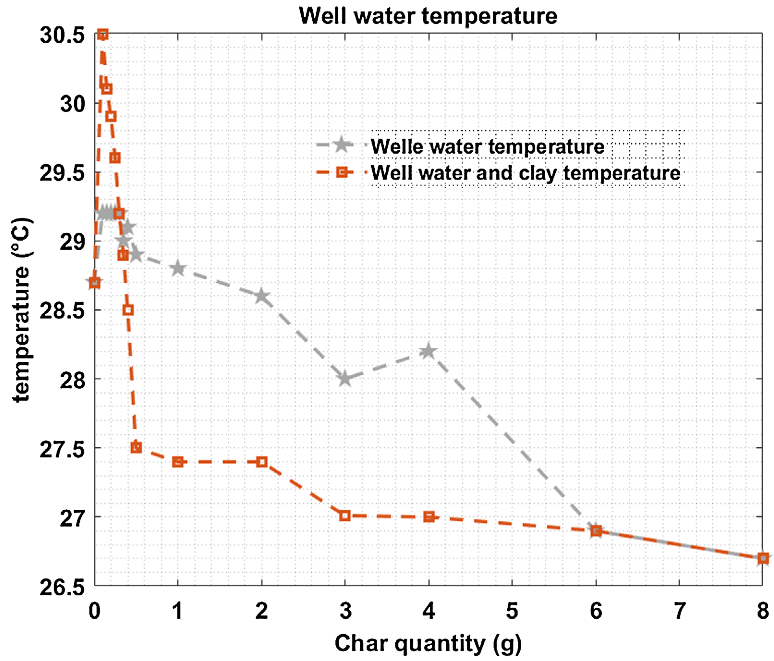

Figure 7. Change in well water temperature as a function of the amount of ditakh char.

Any sudden change in this parameter can therefore lead to a change in water quality [7]. According to our analyses, we observe that the addition of char does not cause a significant change in temperature (**Figure 7**). However, between 0 and 2 g of char, the temperature decreases rapidly. The addition of clay accentuates this reduction. Above 2 g of char, the decrease in temperature becomes less significant. This drop in temperature may be due to endothermic reactions related to the adsorption of compounds on the char.

3.1.4. Total Dissolved Solids (TDS)

Le TDS represents the total concentration of substances (ions) dissolved in water. It consists of inorganic salts (calcium, magnesium, potassium, carbonates, nitrates, bicarbonates, chlorides, and sulfates), some organic matter from human activities, and a number of natural sources. A high TDS concentration alone is not harmful to health, but it can have undesirable effects (staining household appliances, corroding pipes, and causing a metallic taste) [1].

The acceptable value according to the OMS must be less than 650 ppm. As shown in Figure 8, TDS increases with the amount of char added, particularly above 2 g. However, between 0 and 2 g, TDS varies from 200 to 300 ppm, which guarantees satisfactory water quality. An optimal char dosage, not exceeding 2 g, preserves good water quality while limiting total dissolved solids.

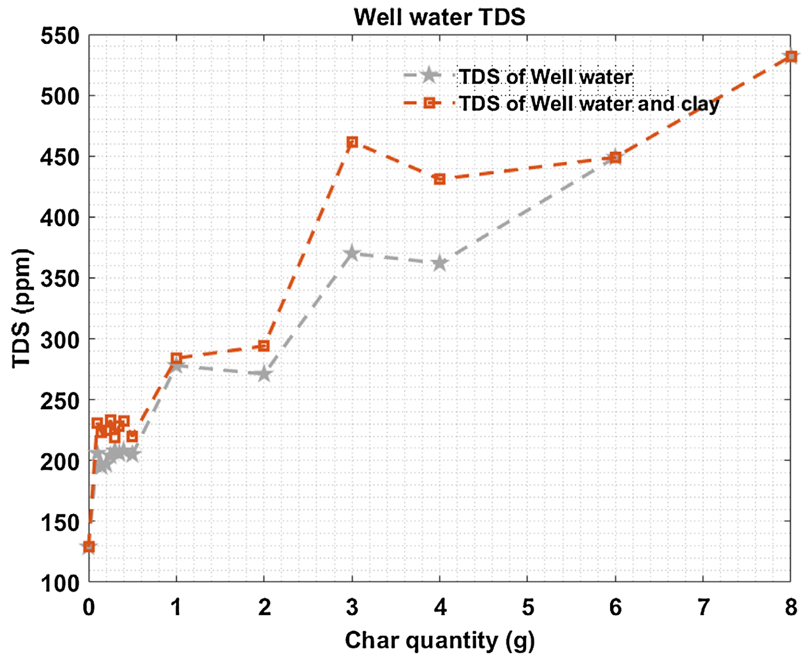

Figure 8. Change in TDS of well water depending on the amount of ditakh char.

3.2. Analyzing the Effect of Different Types of Activated Char in a Fired Clay Tank

After determining the optimal amount of char, which is between 0 and 2 g to treat 200 g of water, the next step is to identify the most effective type of char based on the parameters analyzed.

3.2.1. On Electrical Conductivity

Figure 9 illustrates the influence of coal type on the electrical conductivity of well water based on different coal masses. However, conductivity clearly shows that activated ditakh coal and non-activated wood coal weighing 1 g exhibit good water conductivity of 200 g. However, well water treated with non-activated ditakh char has the lowest conductivity values. Char is stable and acceptable, while non-activated ditakh char is less effective.

This increase can be explained by Ditakh's char reactivity and adsorption capacity. On the other hand, char, which is more stable, could be a good alternative in regions where activated Ditakh char is unavailable.

3.2.2. On the pH of Water

However, regarding the impact of different types of char on physical parameters, we observe that the pH of the water increases with char and activated ditakh char to reach 7.3 and 6.8 respectively, while there is an excessive increase (5.15 - 9.46) with non-activated ditakh char (Figure 10). This can be explained by the fact that char has a low adsorbing effect on water due to the small size of its pores. On the other hand, non-activated ditakh char makes the water more alkaline, while activated ditakh char first adsorbs the folding chemical components, followed by neutralization.

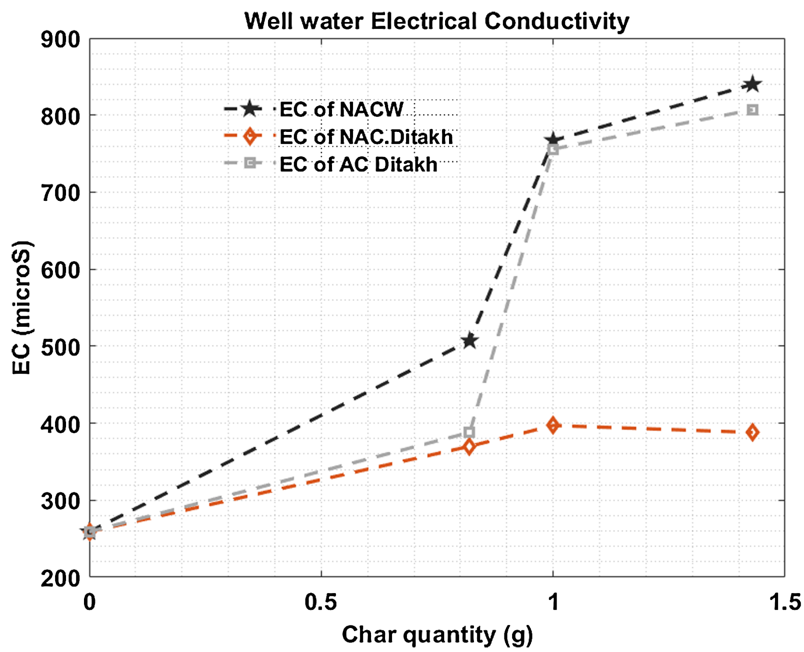

Figure 9. Influence of coal type on the electrical conductivity of well water in the presence of clay, depending on different char masses.

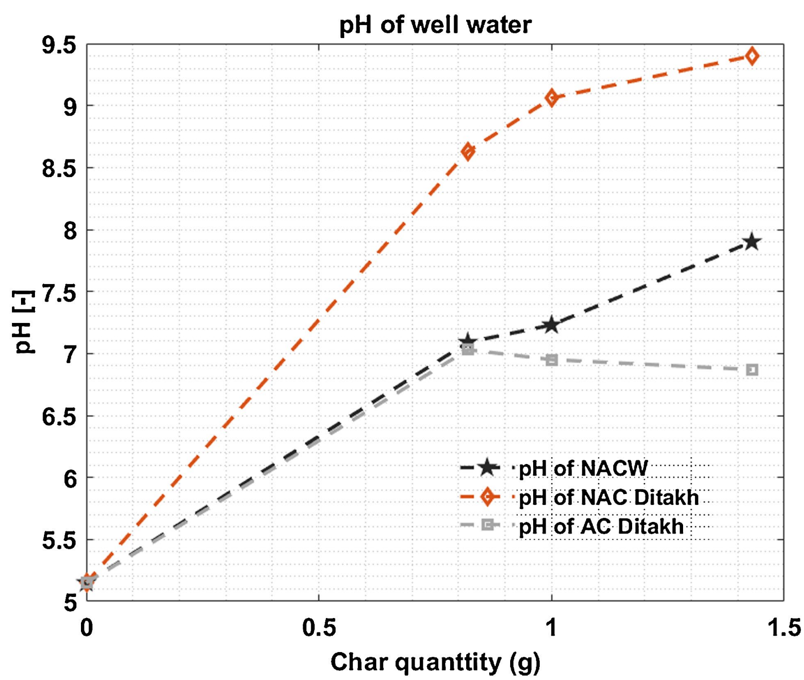

Figure 10. Influence of coal type on the pH of well water in the presence of clay, depending on different char masses.

Therefore, in addition to the optimal amount of char, it is essential to take into account durability and turbidity in order to determine the amount that is truly appropriate for treating this well water.

3.2.3. On Total Hardness of Water

The total hardness of water, or the calcium and magnesium ion content, corresponds to the amount of calcium and magnesium dissolved in the water. The more stable this amount is, the more the water is said to be soft or aggressive; the higher this amount is, the more the water is said to be hard or calcareous. This parameter can be classified as follows based on calcium carbonate ($CaCO_3$): soft water, from 0 to 6 ˚f; moderately hard water, from 6 to 12 ˚f; hard water, from 12 to 18 ˚f; very hard water, 18 ˚f and above [7]. As shown in **Figure 11**, the hardness of well water varies depending on the type of carbon and the amount used, but remains stable for amounts of 0.8 g and 1 g of activated carbon (AC). Thus, for optimal treatment of 200 g of well water, activated char is preferable because it offers consistent results for quantities between 0.8 g and 1 g.

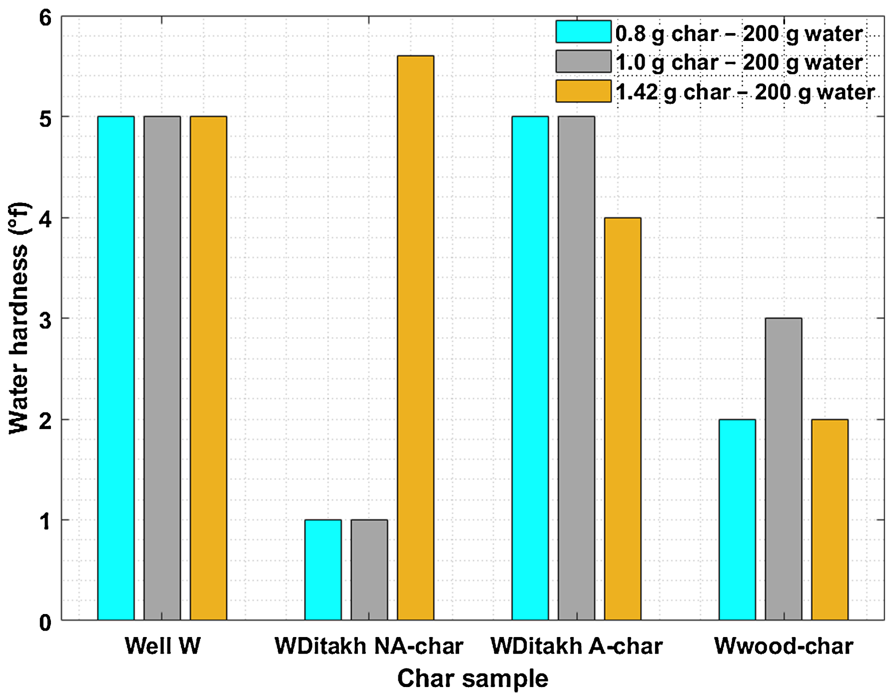

Figure 11. Total hardness values of well water in the presence of clay, depending on different char masses.

3.2.4. On Turbidity of Well Water

Turbidity is a parameter that expresses the optical properties of water to absorb or scatter light, and is caused by the presence of finely divided suspended matter (clay, silt, etc.). High turbidity can allow microorganisms to attach themselves to suspended particles: the bacteriological quality of cloudy water is therefore suspect [8]. The OMS has recommended a maximum permissible turbidity limit of less than 5 NFU (<5 NFU). As shown in **Figure 12**, the turbidity of well water varies depending on the type and quantity of carbon used. In particular, with 0.8 g of Ditakh activated carbon, turbidity becomes that tends toward zero (0.04 NFU), indicating excellent water clarification capacity.

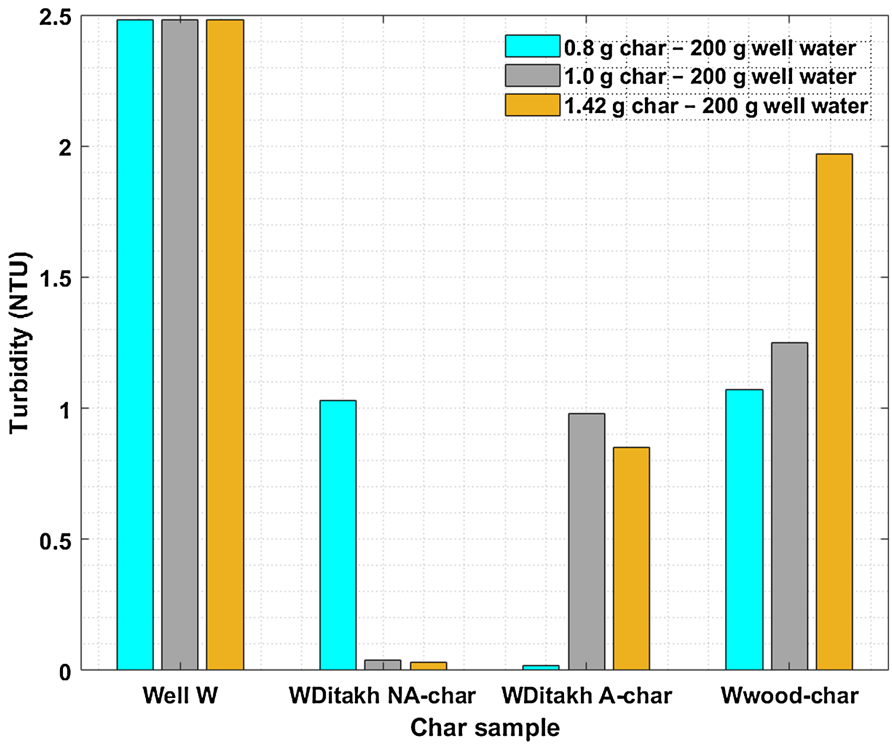

Figure 12. Turbidity values of well water in the presence of clay according to coal types.

This shows that using 0.8 g of this carbon per 200 g of water is particularly effective in reducing turbidity.

4. Conclusions

In summary, the initial analysis revealed the nature of the water samples, enabling this study on the use of char obtained from local biomass for water treatment to be carried out. The results of this study first enabled the effect of the quantity of char on the physical parameters of the water to be analyzed. They then identified activated char as the most effective type of char for improving water quality. We noted in this study that an initially acidic pH became close to 7, and an initial EC of 268 µS/cm became more mineralized following the treatment of well water with char. Finally, they determined the optimal amount of char to use. It is therefore recommended to use between 0.8 and 1 gram of activated char or non-activated char for a volume of 200 grams of water.

However, further research is needed to assess the long-term impact of activated char use on public health. This also includes exploring its potential applications in other areas such as:

- agriculture, for soil management and agricultural water filtration;
- waste treatment through the recovery of local materials;

- biofuel processing, and infected wounds.

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Conflicts of Interest

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

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