

Full Length Research Paper

Local biomass valorisation in activated char production and methods for treating well water in Ziguinchor

Ansoumane DIEDHIOU^{1,2*}, Célestin SAMBOU¹, Mamadou Seydou BA¹ Babacar BADJI¹ and Ammar BENSAKHRIA²

¹Laboratoire de Chimie et de Physique des Matériaux, Université Assane Seck de Ziguinchor, Ziguinchor, Sénégal.

²Centre de recherche de Royallieu, Université de Technologie de Compiègne, EA 4297-TIMR, BP20529 - 60205 Compiègne, France.

Received 10 October, 2025; Accepted 3 December, 2025

This study focuses on the physicochemical quality of well water in Ziguinchor and a possible treatment method using activated char made from dried *Parkia biglobosa* wood, coconut shells, and Cayor apple tree shells, followed by treatment using a combination of fine sand and activated char. The study of physicochemical parameters such as electrical conductivity, total dissolved solids (TDS), and potential of hydrogen (pH) in water from different sites (Château d'Eau, Néma Kadior, Goumel, Kénia, and Diabir) revealed significant irregularities in these parameters, particularly in July. Two categories of water were identified: water with low conductivity (125 to 606 μ S) and water with high conductivity (1599 to 1994 μ S), with acidity (4.45 to 6.4). Based on this information obtained from the treatment of water samples taken during this period, it was important for us to propose a treatment method consisting of fine sand combined with unused local biomass, available and easy to activate. It was then proven that the best results in terms of conductivity, pH and temperature were obtained from treatments with activated char based on dry local biomass. Finally, the study revealed that treatment with powdered activated char gives the water better physicochemical quality than treatment with granulated activated char, regardless of the type of biomass used. This treatment technique can therefore be a sustainable solution for improving water quality.

Key words: Activated char, biomass, electrical conductivity, potential of hydrogen (pH).

INTRODUCTION

Water is commonly referred to as the 'source of life' because of its fundamental role for all living organisms. Without water, no form of life can survive, which is why it is often at the heart of global concerns about sustainable development. Whether for human consumption, agriculture, or industrial processes, access to quality water is essential. However, many regions around the world, including sub-

Saharan Africa, face serious problems with water availability and quality. Senegal is no exception to this reality, particularly the Ziguinchor region, where water quality poses significant challenges to public health, food security, and local economic development.

The situation in Ziguinchor is worrying due to the deterioration in the quality of available water (Ardila et

*Corresponding author. E-mail: ansoumane.diedhiou@univ-zig.sn.

al., 2024). There are multiple causes, including salinization, demographic density (Akhtar et al., 2021; Ardila et al., 2024), biomass residues, and poor environmental management. The region's water has an unfavorable or questionable physical and chemical composition, often making it unfit for direct consumption. This situation increases the risk of waterborne diseases, particularly in rural areas where water treatment infrastructure is nonexistent or inadequate. Improving water quality is therefore an urgent priority for the city of Ziguinchor in particular, and it is essential to find appropriate solutions that are both accessible and sustainable. Water treatment is a key issue in ensuring harmonious development and protecting the health of the population. In the case of the city of Ziguinchor, solutions must be economically viable, environmentally sustainable, and adapted to local realities. There are many traditional methods of water purification, but they are little known (use of canaries) and the use of mineral charcoal, which requires complex infrastructure or chemicals (biochemical membrane and reverse osmosis). Water is treated by coagulation, flocculation, filtration, and chlorination before being distributed for consumption, or by using household filters (sand, ceramic, activated char) or disinfection products (chlorinated products). Biochar is a form of char obtained through pyrolysis, a process of thermal decomposition of biomass in the absence of oxygen. This technique transforms organic matter such as biomass waste, into a material with remarkable properties for adsorbing pollutants in water (Merlo et al., 2025). The use of activated char for water treatment is widely recognized around the world. Due to its physical structure and adsorption properties, activated char is used to remove a wide variety of contaminants, including heavy metals, chemical residues, and organic pollutants (Husien et al., 2022; Al-sareji et al., 2023; Gulamhussein et al., 2023). Numerous studies have proven its effectiveness in various contexts, ranging from large urban water treatment facilities to more local and rural solutions (Bury et al., 2021; Ajen et al., 2023; Daniel et al., 2023). However, large-scale activated char production can be costly and relies on non-renewable raw materials, posing sustainability challenges, particularly in low-income regions.

However, to ensure better drinking water quality, various physical-chemical and microbiological parameters are taken into account, although this study will only address physical-chemical parameters. The physico-chemical parameters studied in this study are: electrical conductivity, hydrogen potential (pH), total dissolved solids (TDS), temperature, and electrical voltage of the water. The objectives of this study are to conduct a study of the physico-chemical quality of well water in the municipality of Ziguinchor so that, ultimately, treatment by adsorption on activated char from various types of biomass, such as coconut shells, dry wood, and caya apple nuts can be carried out. In order to conduct this study properly, various periodic samples (July, August,

October, and November) were taken in different areas within the municipality of Ziguinchor, including Goumel, Néma Kador, Château d'Eau, Kénia, and Diabir, in order to assess the periodic evolution of the physico-chemical parameters of these water samples. Based on the results obtained, it was noted that the water in July was most affected by these variations in physico-chemical parameters and will therefore be treated by adsorption on activated char. Thus, in order to achieve the objectives, various materials and methodologies were adapted and presented.

MATERIALS AND METHODS

The materials used to carry out this study are diverse and varied, including the different types of biomass used and their activated chars, as well as the equipment. Also, the methods used to prepare the activated char and the study area was presented.

Presentation of the different types of biomass and their activated chars

The biomass and sand used for this study were obtained from Ziguinchor. They were pretreated; however, only the types of biomass underwent pyrolysis followed by chemical activation. The images obtained before and after pyrolysis are shown in Table 1.

Equipments

The various devices used to carry out this work are presented here. A conductivity/pH/TDS/temperature meter was used to measure physical and chemical parameters (conductivity, pH, TDS, and temperature). We used a GPS device to provide the exact location of the sampling sites. During the sample preparation period, a muffle furnace, an oven, and an electronic balance were used. We also used a spectrofluorometer for spectral characterisation of emissions as a function of wavelength for our samples in their initial and activated states.

Method of preparing activated char

To prepare the activated char, various steps, which are listed and explained, were carried out:

Step 1: This first step, considered a pre-treatment step, consists of washing the raw material with tap water, rinsing it with distilled water, and then drying it in an oven for 24 h at a temperature of 105°C. The purpose of this washing step is to avoid the risk of contamination of the raw material to be used.

Step 2: The second step is pyrolysis. This involves placing a quantity of raw materials in an oven at a temperature of 450°C. To do this, a quantity (400 g) of raw material (coconut shells, dry wood, caya apple nuts) was placed in the muffle furnace. After the introduction, heat transfer between the furnace and the material occurred, followed by the release of char dioxide after a short time; this is the beginning of carbonisation. After a few minutes, a complete cessation of heat release, a sign that carbonisation had ended, was noted; this is how non-active char is obtained.

Step 3: In this stage, called activation, the char in a 50% diluted

Table 1. Presentation of biomass types and their activated char.

Names of samples	Samples	Activated carbon
Coconut shell (CN-Shell)		
<i>Parkia biglobosa</i> wood (PB-Wood)		
Cayor apple tree shell (CAT-shell)		
Fine sand		Not activated

potassium hydroxide (KOH) solution for 16 h was immersed. After 16 h of impregnation, the impregnated char was recovered and then placed it in a furnace at a temperature of 450°C for 60 min. The char was then removed from the oven and washed thoroughly with a solution of hydrochloric acid (HCl), then sequentially with distilled water until the pH of the wash water was close to 7.

Step 4: This fourth and final step is drying. As the name suggests, the washed sample in an oven at 105°C for 24 h was placed. The resulting product is dry-activated char ready for water treatment. However, it should be noted that the impregnation stage can precede the pyrolysis stage: this is pre-impregnation. It was even preferred and adopted in this study because it facilitates the washing of activated char. Thus, for the use of activated carbon in water filtration, standards such as NSF/ANSI 61 (materials for drinking water systems) and AWWA B604 (granular activated carbon) have been used.

Study area

Samples were taken in various locations within the municipality of Ziguinchor, such as Château d'eau, Néma Kadjor, Goumel, Kénia, and Diabir, in July, August, October, and November. These sites are shown on the map, which was created using geolocation coordinates obtained via GPS. After each sampling session, the initial physicochemical parameters (conductivity, pH, and TDS) were measured. In order to conduct this study properly, various periodic samples (July, August, October, and November) were taken in different areas within the municipality of Ziguinchor, including Goumel, Néma Kadjor, Château d'eau, Kénia, and Diabir (Figure 1) in order to obtain the periodic evolution of the physicochemical parameters of these sampled waters. Based on this information obtained, it was noted that the water in July is the most affected by these variations in physicochemical parameters and will therefore be treated by adsorption on activated carbon.

Thus, in order to achieve our objectives, various materials and methodologies were adapted and presented.

Firstly, it was noted that conductivity varies according to the sites and periods (months) of sampling. Between July and August, low conductivities ranging from 100 to 300 μS for the Château d'Eau, Néma Kadjor, Kénia, and Diabir sites were obtained. However, a high conductivity (1600 to 1700 μS) for the Goumel site was noted.

On the other hand, it appears that the pH of the water, depending on the month of sampling, is acidic (4.45 to 6.4) for all areas (Château d'Eau, Néma Kadjor, Kénia, Diabir, and Goumel). It was based on these irregularities (conductivity, pH, and TDS) that the idea of treating this water arose, yielding the results presented subsequently.

RESULTS AND DISCUSSION

The physical and chemical parameters studied in this present study are: electrical conductivity, pH, TDS, temperature, and electrical voltage of the water. The objectives of this study are to conduct a study of the physico-chemical quality of well water in the municipality of Ziguinchor in order to ultimately carry out treatment by adsorption on activated char from various types of biomass, such as coconut shells, dry wood, and cayor apple nuts.

Water treatment using char from different types of biomass

Variation in conductivity and pH

The water samples were treated separately with three

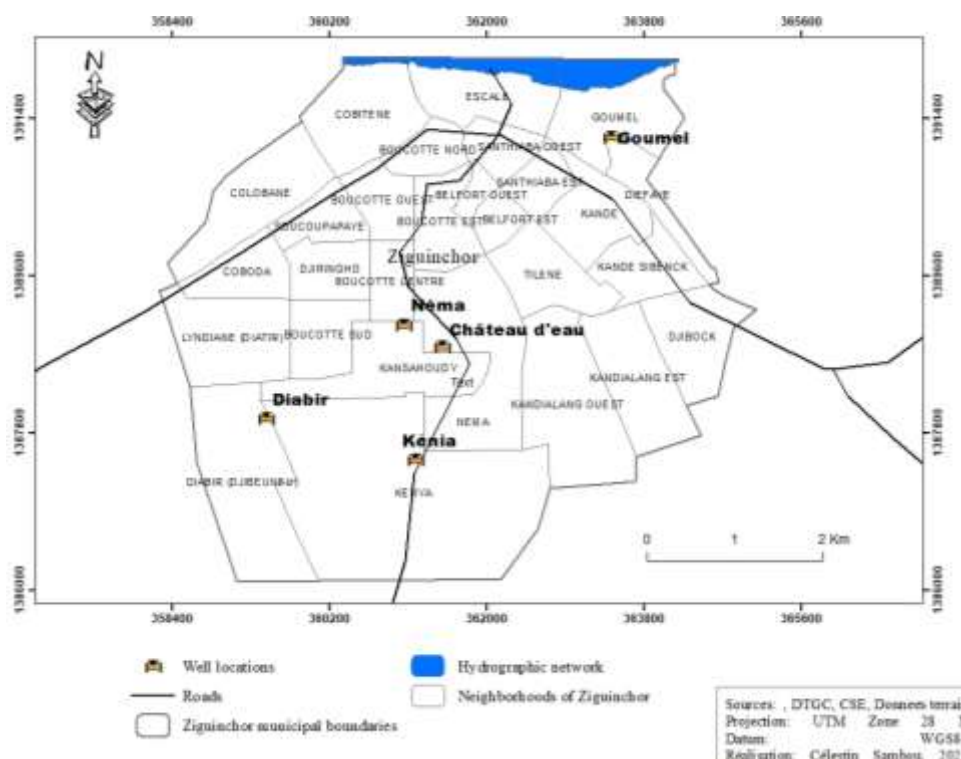


Figure 1. Geographical location of the well water extraction area of Ziguinchor.

activated char filters made from different types of biomass (*Parkia biglobosa* bios, coconut shells, and cayor apple tree shells), and the results obtained were used to study their effect on the evaluation of electrical conductivity and pH over time.

Effect of biomass type on water conductivity: Low-conductivity waters such as Château d'eau, Néma Kadjor, Kénia, and Diabir were note; there is an increase in conductivity depending on the adsorption or activated char treatment time (Figure 2). These results are consistent with those of Rania (2024). This increase in conductivity may be due to the potential regeneration of potassium K^+ and chloride Cl^- crystals present in activated char activation solutions such as potassium hydroxide KOH and hydrochloric acid HCl, as well as many other ionic crystals present in carbon such as Ca^{2+} , Mg^{2+} , Fe^{2+} , Cl^- ions, etc. This phenomenon of increased electrical conductivity is accompanied by chemical activity involving ion transfer between the two media (solid and liquid). The principle of ion exchange is based on the reversible exchange of ions between a solution and a solid. In addition, the dielectric constant, which does not change during the formation of surface hydroxyl groups (water chemisorption), shows a sudden variation when the amount of adsorbed water increases. Water molecules undergo a change in orientation due to the

electric field that prevails near the surface and the hydrogen bonds that form.

On the other hand, in Figure 2, for water with high conductivity (Goumel), a considerable decrease in conductivity as a function of adsorption time (char-water contact) was seen. This decrease in conductivity could be due to significant adsorption of certain crystals or mineral salts initially present in the water. However, it has been found that the increase in conductivity of water treated with dry wood-based activated char is much greater than that of water treated with coconut shell-based char, which in turn is much better than that of water treated with Cayor apple tree-based activated char. The same is true for sites with high water conductivity. Conclusion was made that the type of sample has an effect on the electrical conductivity of water, which could be due to the physical and chemical composition of the raw material.

Effect of biomass type on water pH: Figure 3 shows that the pH of the water increases as the adsorption time increases. These results correlate with the findings of (Thialo, 2024; Rania, 2024). It is also noted that all curves tend towards neutrality ($pH=7$). However, the increase is more regular and greater for adsorption on wood- and coconut shell-based activated char than for adsorption on cayor apple nut-based activated char. This difference may be due to the variety of forms of the

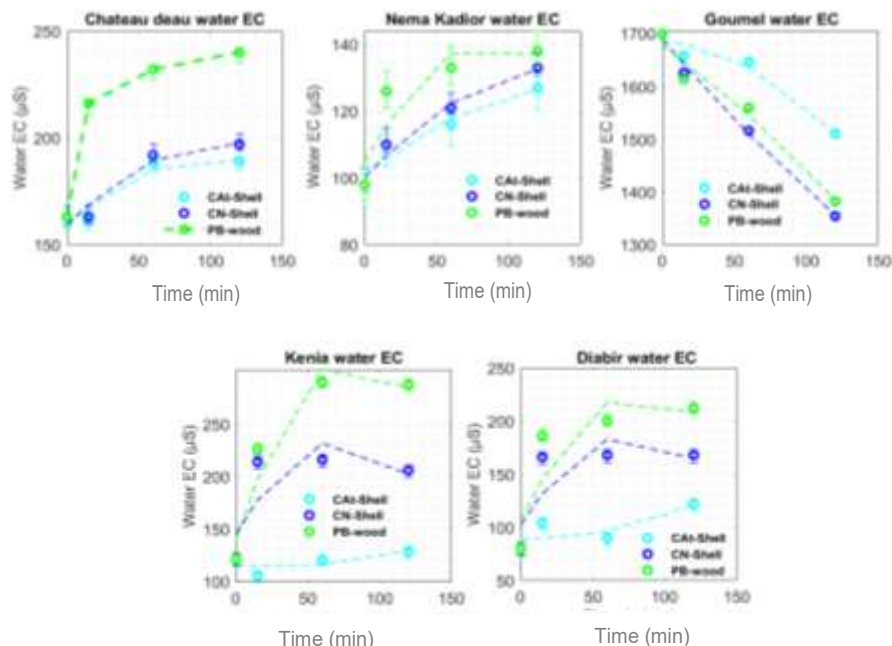


Figure 2. Conductivity evolution as a function of adsorption time and different biomasses.

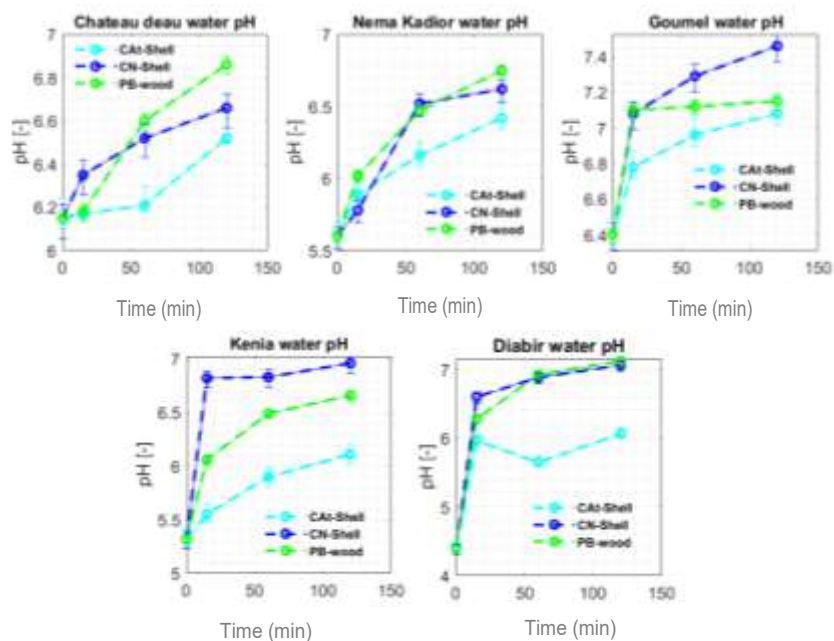


Figure 3. pH evolution as a function of adsorption time and different biomasses.

different activated chars, their specific surface area or the number of pores present in the char (porosity). From this analysis, conclusion was made that for water with a pH below 7, pH regulation would be better using wood-based activated char and coconut shell at the expense of cayor apple nut. From these results, deduction was made that, when activated, wood char and coconut shells have a

much better treatment efficiency than cayor apple nuts. These results can be explained by the different emission spectra of the activated chars shown in Figure 4. These spectra reveal and confirm that dry wood and coconut shells have a better emission capacity at wavelengths between 400 and 800 nm. This indicates an irregularity in the water treatment capacity of activated char based

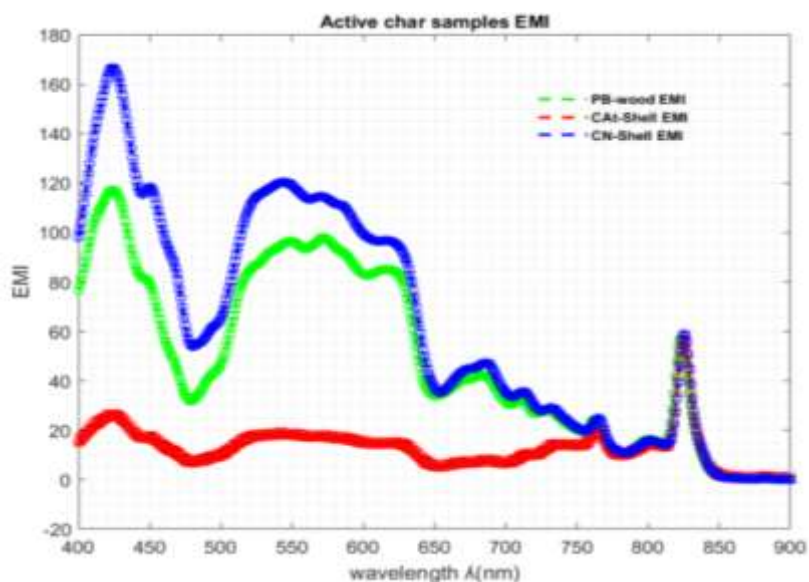


Figure 4. Spectrum of adsorption wavelengths for different types of biomass.

on cayor apple wood, thus confirming the conclusion reached on the effect of biomass on treatment, which favours wood and coconut shells over cayor apple wood.

Study of conductivity and pH variation

Effect of activated char size on conductivity

Measurements of the conductivity variation of two water samples, one from the Château d'Eau and Diabir sites for low conductivity water ($EC < 1300 \mu S$), and the other from Goumel for high conductivity water ($EC > 1300 \mu S$), were carried out using two particle sizes of char samples. The results are shown in Figure 5.

Figure 5 also shows that the conductivity of water from Chateua d'Eau and Diabir increases significantly with adsorption time, regardless of the biomass used and the size of the char. It is noted that the conductivity of the treated water from the Château d'Eau site increases with the adsorption time on activated char based on coconut shells and dry wood. Furthermore, a sharp decrease in the latter was observed between 0 and 60 min, followed by a rapid increase for the Cayor apple tree-based treatment until the highest conductivity values were reached.

However, it is important to note that this increase in conductivity is much greater with adsorption on powdered activated char (PAC) than with granulated activated char (GAC), in line with the results of Khelili et al. (2011). These results reveal that char increases the low conductivity of water, thereby increasing its mineralization for possible compliance with internal or international standards for drinking water.

In the case of water with high conductivity, the conductivity of Goumel water, initially equal to $1700 \mu S/cm$, decreases considerably over time and depending on the size of the activated char was noted. For granulated char treatment, a significant decrease in conductivity, reaching values between 1370 and $1430 \mu S/cm$ was seen. These results are consistent with the results of Kadia (2023). However, this decrease in conductivity is much more significant for powdered char treatment, reaching conductivity values between 1302 and $1350 \mu S/cm$ compared to $1300 \mu S/cm$ (World Health Organisation [WHO] guideline value). In principle, this greater increase in conductivity observed in water treated with powdered activated char suggests that powdered activated char promotes and retains the best regeneration capacity of certain cations present in the char after activation.

Effect of activated char size on pH

Observation was made that the pH of Diabir water, initially equal to 4.45 (acidic), increases exponentially with the adsorption time on activated carbon to reach values between 6.4 and 7.2 , depending on the biomass. This could be due to strong adsorption of hydrogen ions H^+ , or other cations present in the water by the activated char following the decomposition of part of the ozone into OH radicals. However, we note that this increase in pH is much greater when the treatment or adsorption is carried out on powdered activated char. From this analysis, we can deduce that for acidic water, activated char tends to raise the pH to normal values between 6.5 and 8.5 according to WHO standards. It should also be noted that

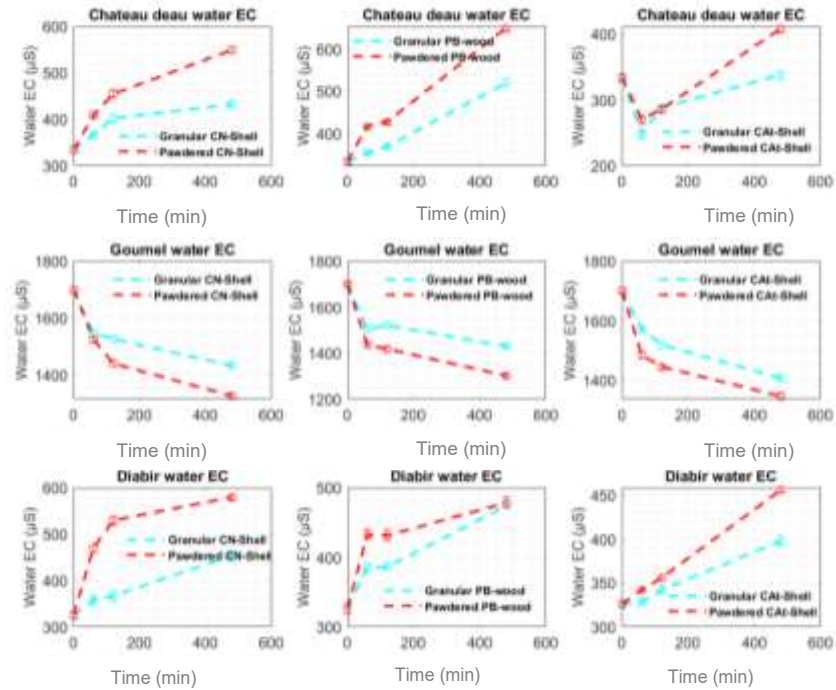


Figure 5. Conductivity evolution at the Diabir, Goumel, and Château d'Eau sites over time for different sizes of activated char.

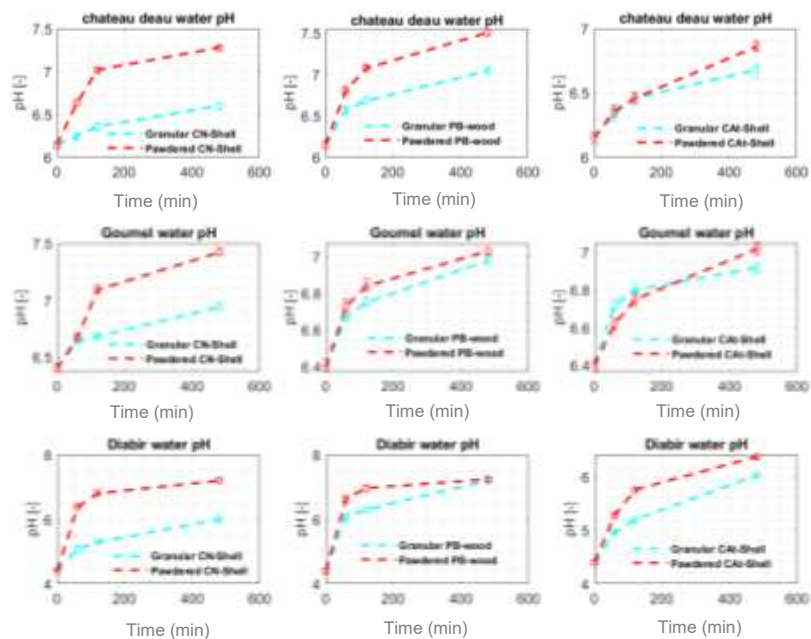


Figure 6. pH evolution at the Château d'Eau, Diabir, and Goumel sites over time for different sizes of activated char.

adsorption on powdered char gives better results in terms of pH regulation for acidic water.

The evolution of the curves in Figure 6 reveals that the pH of the water increases as a function of the adsorption

time on activated char. However, this evolution is much more significant with adsorption on powdered activated char than on granulated char for all biomasses.

It is also important to note that the change in pH occurs

Table 2. Results of the sand-activated Char treatment.

Samples/Parameters	Raw water	Water+Powdered-PB-wood	Water+Sand+Powdered-PB-wood	Water+Granular-PB-wood	Water+Sand+Granular-PB-wood
EC (μS)	1699	1335 $\pm$ 0.06	1301 $\pm$ 0.101	1448 $\pm$ 0.1	1340 $\pm$ 0.08
pH	6.73	7.03 $\pm$ 0.05	7.06 $\pm$ 0.01	6.92 $\pm$ 0.11	6.96 $\pm$ 0.02

in stages, which shows that adsorption could continue as long as the maximum adsorption time was not reached.

As at the other sites, observation was made that the pH of the water increases with the adsorption time on activated char, regardless of the biomass used and the size of the char. However, as at the Diabir site, this increase in pH is much greater when treatment is carried out on powdered activated char than on granular activated char.

Water treatment using activated wood char combined with fine sand

The results of this study reveal that, in line with the results of single char treatment, the conductivity of raw water decreases significantly after sand-activated char treatment (Table 2). However, this decrease is greater with powdered activated char (Powdered-PB-wood) treatment than with granular activated char (granular-PB-wood) treatment, falling from 1699 μS (initial water) to 1301 and 1340 μS , respectively. Ultimately, it is said that this type of treatment gives encouraging results in terms of improving the physical and chemical quality of Goumel water, although we were unable to meet the standards recommended by the WHO (200 to 1300 μS).

Conclusion

The tests carried out during this study aimed to treat water from wells in the municipality of Ziguinchor using activated char adsorption from different types of biomass. The physicochemical quality of the well water in Ziguinchor was studied, and found that the water in July and August was more affected by variations in physicochemical parameters. Thus, after treatment with granulated activated char, it was proven that wood and coconut shells have a better treatment efficiency than cayor apple nuts. Therefore, it was concluded that treatment performance may vary from one type of biomass to another. Furthermore, according to the results of the study on the effect of activated char size on efficiency, it was found that treatment with powdered activated char is more efficient than treatment with granulated activated char. Therefore, the smaller the size of the char, the better the efficiency. At the end of these two treatment tests, it was proven that the conductivity of Goumel water still needs to be improved, although there was a significant decrease in conductivity during the various treatments carried out. This is why the combined of sand and powdered activated char treatment method was used. However, it was noted that although this technique does reduce conductivity more effectively, who standards (between 200 and 1300 μS) have not yet been

achieved, with a reading of 1301 μS ; this represents a challenge to be addressed in a future study. Ultimately, the conclusion was made that activated char treatment, and its combined action with fine sand, are very effective and inexpensive techniques for regulating the physical and chemical parameters of water.

ACKNOWLEDGEMENT

The authors thank the University Assane Seck of Ziguinchor, UFR-ST, and the Physics Department of UASZ, and the Senegal government for financial support for this work.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

- Ajien AZ, Idris J, Nurzawani Md S, Rafidah H, Hazman S (2023). Coconut shell and husk biochar: A review of production and activation technology, economic, financial aspect and application. *Waste Management and Research* 41(1):37-51.
- Akhtar N, Syakir Ishak MI, Bhawani SA, Umar K (2021). Various natural and anthropogenic factors responsible for water quality degradation: A review. *Water* 13(19):2660.

- Al-Sareji OJ, Meiczinger M, Al-Juboori RA, Grmasha RA, Andredaki M, Somogyi V, Hashim KS (2023). Efficient removal of pharmaceutical contaminants from water and wastewater using immobilized laccase on activated carbon derived from pomegranate peels. *Scientific Reports* 13(1):11933.
- Ardila A, Rodriguez MJ, Pelletier G (2024). Optimizing sampling location for water quality degradation monitoring in distribution systems: Assessing global representativeness and potential health risk. *Journal of Environmental Management* 365:121505.
- Bury NA, Mumford KA, Stevens GW (2021). The electro-Fenton regeneration of granular activated carbons: Degradation of organic contaminants and the relationship to the carbon surface. *Journal of Hazardous Materials* 416:125792.
- Daniel LS, Rahman A, Hamushembe MN, Kapolo P, Uahengo V, Jonnalagadda SB (2023). The production of activated carbon from *Acacia erioloba* seedpods via phosphoric acid activation method for the removal of methylene blue from water. *Bioresource Technology Reports* 23:101568.
- Gulamhussein MA, Saini B, Dey A (2023). Removal of pharmaceutical contaminants through membrane bioreactor. *Materials Today Proceedings* 77:260-268.
- Husien S, El-taweel RM, Salim AI, Fahim IS, Said LA, Radwan AG (2022). Review of activated carbon adsorbent material for textile dyes removal: Preparation, and modelling. *Current Research in Green and Sustainable Chemistry* 5:100325.
- Kadia A (2023). Représentation des analyses Hydrochimiques et Adsorption du fluorure des eaux souterraine dans Le Sud Algérien: Cas de cuvette de Touggourt. Doctoral dissertation, UNIVERSITE KASDI MERBAH OUARGLA.
- Khelili H, Achour S, Rezeg A (2011). Efficacité du sulfate d'aluminium et du charbon actif face à des polluants organiques aromatiques. *LARHYSS Journal* P-ISSN 1112-3680/E-ISSN 2521-9782 P' 9.
- Merlo F, Cabrera-Codony A, Ghiglione R, Speltini A, Fontàs C, Anticò E, Profumo A (2025). Activated char embedded in biodegradable film for antimicrobials removal: Towards sustainable water purification. *Journal of Hazardous Materials* 490:137768.
- Rania H (2024). "Traitement Des Eaux Usées Domestiques de La Station d'épuration de HOUD BERKAOUI Par Charbon Actif." Mémoire soutenu à l'Université Kasdi Merbah Ouargla, Faculté des Sciences Appliquées. Département de Génie des Procédés.
- Thialo Y (2024). "Traitement Des Eaux Souterraines Par Filtration Sur Charbon Actif et Sable Fin." 86, Memoire soutenu à l'UASZ, Département de Physique.