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# **Influence of Charring Methods on Surface Characteristics and Sorption Properties of Rice Straw Derived Biochars**

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### **Author's contribution**

*Author DMM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. She also managed the analyses of the study and literature searches. Finally, she read and approved the final manuscript.*

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## **ABSTRACT**

Rice straw derived biochars were prepared by two different charring methods, in order to investigate effect of the preparation procedures on the sorption efficacy toward heavy metals from aqueous solutions.

The preparations of the biochars were under limited oxygen conditions, including one step heating treatment at 450°C/60 min. (Char 450) and two steps heating treatment upto 700°C/60 min. (Char 700). Influences of the charring methods on the surface characteristics of the obtained biochars were examined via scanning electron microscopy coupled with Energy Dispersive X ray Spectrometry (SEM-EDAX) and Fourier transform infrared spectroscopy (FTIR) analyses. The sorptive properties of Char 450 and Char 700 were evaluated according to their efficacy towards the removal of Cu<sup>2+</sup> ions from the aqueous solutions. The sorption isotherms of Cu<sup>2+</sup> onto the prepared biochars were analyzed by Freundlich and Langmuir models. Kinetic studies were also carried out. Enhancements of the porous structure and some elemental content were depicted in Char 700 compared with Char 450, indicating the remarkable effect of the charring methods on surface

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properties of biochars. Both sorbents were able to remove all the  $\text{Cu}^{2+}$  ions at low initial sorbate concentrations and within 15 min. of contacting time. Further increase of the sorbate initial concentrations, Char 700 exhibited higher sorption efficiency than Char 450, achieving 66 and 55 % removal percentages, respectively.

At  $2.0 \times 10^{-3}$  M initial  $\text{Cu}^{2+}$  concentration, two hours of contact time were enough for the sorption of 69 % of the total ions. Langmuir isotherm equation and pseudo second order kinetic models successfully describes the sorption of  $\text{Cu}^{2+}$  onto the studied sorbents. Chemisorptions processes were assumed to be the domain sorption mechanisms.

The study indicated the potential use of the rice straw derived biochar as low cost sorbent in the field of wastewater treatment, taken in consideration the role of preparation conditions.

*Keywords: Biochar; charring conditions; wastewater; heavy metals; rice straw.*

## 1. INTRODUCTION

Rice is one of the important crops in Egypt. The Egyptian production of rice can be considered of the largest among the Near East countries [1]. On the other hand, the rice production generates environmental problems via the conventional management of the crop residues. The main residues of rice fields are rice straw. Egyptian production of rice straw reached to 3.5 million tons annually [2], these residues are burned in open fields as a farmer disposal practices causing spread black smoke not only on the source area but extended to other far areas, which known by black cloud phenomena, leading to severe environmental pollution. According to the current environmental law of Egypt, the farmer will be fined if he continues this practice. Thus urges to find out other processes which can accommodate the continuous production of these wastes yearly.

Nowadays, rice straw is used as feed stock in power plants to produce thermal gas or biofuel like bioethanol [3]. Furthermore, it can be used as alternative material to the activated carbon, after converting to biochar, due to its high content of carbon. Biochar is produced by charring the agricultural biomass or waste under no or limited oxygen conditions. Thus, biochar as economic and environmentally material has the potential to replace Coal in its uses, such as the utilization in the field of water treatments [4].

Different studies reported the immobilization effect of biochar for organic and inorganic pollutants, when it applied to contaminated soils [5 and 6]. The sequestration potential of biochar materials toward inorganic pollutants suggested the use of these materials for the removal of heavy metals from aqueous solutions.

Heavy metals are considered of the most toxic pollutants have a global attention due to their

abundant in the environment and resistant to the biological degradation, in addition to their hazardous impacts on the human and all ecosystems. They are discharged to the water bodies mainly via the industrial and agricultural activities [7]. In this study  $\text{Cu}^{2+}$  metal ions is selected as example of heavy metals, which has worldwide concern. Although copper is one of the essential micronutrients, plays a vital role for plant and animal growth, it becomes a toxic metal when increases than certain level. For human, copper is absorbed in the intestines reaching to the red cells and cannot be rid easily from the blood. The higher intake or the existence over the appropriate limit causes sudden circulatory collapse and decomposition of the red cells [8]. Additionally, it may lead to liver and kidney damage and might cause death. Copper releases to the environment via agricultural activities; through the agrochemicals such as fertilizers and some copper compounds used for treating plant diseases like mildew; and via the industrial activities such as electroplating, dyeing and mining [9 and 10]. It reached to the surface water as soluble compounds or free copper ions and can also enter the groundwater [8]. Sorption is one of the potent techniques used for the removal of heavy metals from the aqueous media. Whereby, the sorbent materials and the simplicity of the methods are crucial factors for the broad application of such technique [11].

Several studies reported the removal of different pollutants by the biochars produced from various substrates for example: biochar of almond shell was able to remove Ni and Co [12]; rice straw biochar has capacity in the sorption of Cd [7]; and scots pine and silver birch biochars were able to reduce the concentrations of Cd, Pb, Cu and Zn from polluted aqueous solutions [13]. Efficacy of biochar in the field of water treatments mainly depends on its surface properties. The charring methods and temperature may affect

the chemical and physical characteristics of the produced biochar.

Many factors are included in the preparation of biochars, including the feedstock (source and type of raw materials) and the processing conditions such as pyrolysis methods as well as the treatments after pyrolysis, which ultimately might affect their properties and sorption capacities [14-16]. Nevertheless, the effects of charring rate and temperature on the surface characteristics of rice straw biochars, or their impact on the sorption characteristics have not been fully assessed.

The objectives of this study are i) to compare two different charring temperatures rates (450°C and 700°C) on the surface characteristics of rice straw derived biochars. ii) to assess the sorptive properties of the yielded biochars related to the charring treatments via batch techniques. iii) to analyze the influence of different parameters such as concentration of pollutant and the contact time on the sorption processes of  $\text{Cu}^{2+}$  ions.

## 2. MATERIALS AND METHODS

### 2.1 Materials and Chemical Reagents

Rice straw was collected from Menufya governorate, Egypt. The materials were cut into small pieces of about 4-5 cm in length. Then, they were oven dried at 40°C.

All chemicals used in the study;  $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$ , HCl, NaOH and NaCl; are analytical grades and were obtained from Flukachemika.

### 2.2 Biochar Preparation

Rice straw pieces were charred in muffle furnace (WiseTherm programmable digital PID Control, Korea) under limited oxygen conditions. The charring methods included one or two steps heating treatments. The rice straw materials were charred at 450°C/60 min. as one step heating treatment and the resulted materials denoted by Char 450. The two steps heating (slow raising temperature) treatment started by increasing the charring temperature gradually from 40°C to 170°C/30 min. and then the temperature were elevated upto 700°C/60 min. at a heating rate of 5°C  $\text{min}^{-1}$ , the yielded materials denoted by Char 700. Afterward, the chars yield were milled after being cooled to

ambient temperature and kept in sealed vials for the further work. The char yield was calculated as percentage from Eq.(1)

$$\text{Yield (\%)} = (\text{Char weight})/(\text{Raw weight}) \times 100 \quad (1)$$

Where Char weight and Raw weight are the mass of rice straw per gram after and before the heating treatments, respectively. The charring procedures were repeated three times and the obtained results are the means.

### 2.3 Characterization of Biochar

Cation exchange capacities (CECs) of the charred materials were determined by ammonium acetate methods, where the potassium ions were displaced the ammonium ions on the exchanged sites [17]. Ash and volatile matter were established by the weight loss after heating at 700°C and 950°C, respectively, followed the standard and the modified methods of ASTM [18].

Scanning electron microscopy coupled with Energy Dispersive X-ray Spectrometry (SEM-EDAX) and Fourier transform infrared spectroscopy (FTIR) analyses were performed in order to record the changes in surfaces characteristics of the charred materials as well as the elemental composition and types of the functional groups, according to the heating treatments. SEM-EDAX analyses were carried out on the charred materials before grinding. Where, the materials were mounted on samples holder and subjected for analyses using Quanta FEG 250 at different magnifications. Samples for FTIR analyses were oven dried at 40°C/24 h, and then each material was compressed after mixing with KBr. The spectra were produced using Jasco FT/IR-4100 Fourier transform infrared spectrometer in the range of 600 – 4000  $\text{cm}^{-1}$  wavenumber.

### 2.4 Sorption Experiments

Sorption experiments were performed by batch technique using the yielded biochars, Char 450 and Char 700. The sorption isotherm experiments of copper ( $\text{Cu}^{2+}$ ) were conducted using solid concentration of 0.2 % and solutions of 0.01 M NaCl at pH value 4.1  $\pm$  0.2 (adjusted by 0.1 M HCl and 0.1 M NaOH), containing pollutant concentrations ranged from 0 to  $3 \times 10^{-3}$  M of  $\text{Cu}^{2+}$  ions. Samples were agitated at 250 rpm/ 24 h at ambient temperature followed by centrifugation at 4000 rpm for 15 min.

Kinetic studies were performed at time intervals between 10 to 1440 min. in order to assess the impact of contact time on  $\text{Cu}^{2+}$  sorption by the rice straw derived biochars. Since the experiments were performed using two initial concentrations  $0.5 \times 10^{-3}$  and  $2.0 \times 10^{-3}$  M of  $\text{Cu}^{2+}$  and all other experimental conditions and steps were similar to those applied at the isotherm sorption experiments.

Afterward, the supernatants obtained from the isotherm and kinetic experiments were analyzed by PerkinElmer atomic absorption spectroscopy Analyst 400 (AAS).

Blank samples were prepared parallel with the sorption samples containing biochar without pollutant and with no sorbent containing pollutant. All the sorption experiments were conducted in duplicates to ensure repeatability and mean values were considered. The sorbed amounts of  $\text{Cu}^{2+}$  were calculated by the difference between the initial and the final  $\text{Cu}^{2+}$  concentrations. The removal efficiency of ion was calculated by Eq. (2).

$$\text{Removal efficiency (\%)} = \frac{\text{(The sorbed amount)}}{\text{(Initial ion concentration)}} \times 100 \quad (2)$$

## 2.5 Sorption Models

The experimental data obtained from the sorption of gradient concentrations of  $\text{Cu}^{2+}$  were analyzed using Freundlich (Eq. 3) and Langmuir (Eq. 4) isotherm models and their estimated parameters, maximum sorption and sorption affinities, were calculated from the linear form of those equations [19,20].

$$C = k_f C_f^{1/n} \quad (3)$$

$$C = \frac{b k C_f}{1 + k C_f} \quad (4)$$

where C is the sorbed amount of  $\text{Cu}^{2+}$  per unit mass,  $C_f$  is the final concentration of  $\text{Cu}^{2+}$  ions in the solution,  $k_f$  and  $1/n$  are the adsorption capacity and the adsorption intensity of Freundlich isotherm, respectively, and b and k are the maximum adsorption capacity and the Langmuir affinity constant, respectively.

The Langmuir affinity constant (k) can be used to calculate an important parameter called separation factor; F [21]. This factor helps in detect the affinity between the sorbent and the sorbate. Wherein the F value between 0 – 1 indicates the favorable sorption process and the

value > 1 expresses the unfavorable sorption [11]. F value can be expressed by the following Eq.(5).

$$F = 1 / (1 + k C_i) \quad (5)$$

where  $C_i$  is the initial ion concentration Lagergren pseudo-first order (Eq. 6) and pseudo second order (Eq.7) kinetic models [22] are suggested to investigate the performance of Char 450 and Char 700 towards the removal of low and high concentrations of the pollutants under different time intervals.

$$\text{Log}(q_e - q_t) = \text{log}(q_e) - (k_s/2.303) / t \quad (6)$$

$$t/q_t = 1/(k_2 q_e^2) + 1/q_e t \quad (7)$$

where  $q_e$  and  $q_t$  are the amount of the metal ions sorbed at equilibrium and at time (t), respectively.  $k_s$  and  $k_2$  are the rate constants of the pseudo-first and second order for the sorption processes.

SigmaStat software, ver.3.5, was employed throughout to obtain the statistical parameters such as the mean, standard error and other statistical parameters of the fitted models. Further, the coefficient of determination is the statistical function that used for evaluation the isotherm equations and the kinetic models that fits and expresses the sorption data.

## 3. RESULTS AND DISCUSSION

### 3.1 Characterization of Rice Straw Derived Biochars

Chemical properties and some elemental components of Char 450 and Char 700 are presented in Table (1). Decreasing in the yield percentages, volatile matter, C content and the CEC values were obtained with the slow raising of the charring temperature, however, increasing in the ash content were recorded. In addition, the Energy Dispersive X-Ray elemental data (EDAX) showed enhancement of potassium and silicon content with increasing the heating temperature. The reduction in the yielded biochars and the CEC values noted with increasing the charring temperature were in agreement with those resulted by other work carried out on different feedstock (sugarcane; [23]). They also explained that the enhancement of the ash percentages might be resulted by the increasing of pH and electrical conductivities values of the produced biochars. Thus consequently, increase the

elements contents (Si and K). Biochar mainly composed of labile and stable constituents [24]. The volatile materials may relatively represent the labile and easily decay components. Raising the charring temperature reduces the labile form, indicated by the decrease of the volatile matter, and enhances of the stable component, denoted by increasing the ash contents. The recorded changes in the CEC values, volatile matter, carbon and ash contents were in similar trend but differ in the values with those reported previously by study on rice straw biochar [25].

Several bands were recorded from the FTIR spectra of the prepared rice straw derived

biochars Fig. 1. The bands were assigned for different functional groups such as: hydroxyl groups ( $3448\text{ cm}^{-1}$ ); C-H aliphatic chains ( $2923 - 2852\text{ cm}^{-1}$ ) and C=C or C=O aromatic groups ( $1637\text{ cm}^{-1}$ ). In addition to bands at  $785\text{ cm}^{-1}$  that might assign to aromatic C-H, C=O and C=C stretching vibrations [23,24]. All the functional groups recorded on the FTIR spectra of the prepared materials in this research were similar to those reported previously with different biomass derived chars [26]. The presence of functional groups on the surfaces of both rice straw derived biochars provide binding sites for ions, inducing their potentiality as sorbents for different pollutants from aqueous solution.

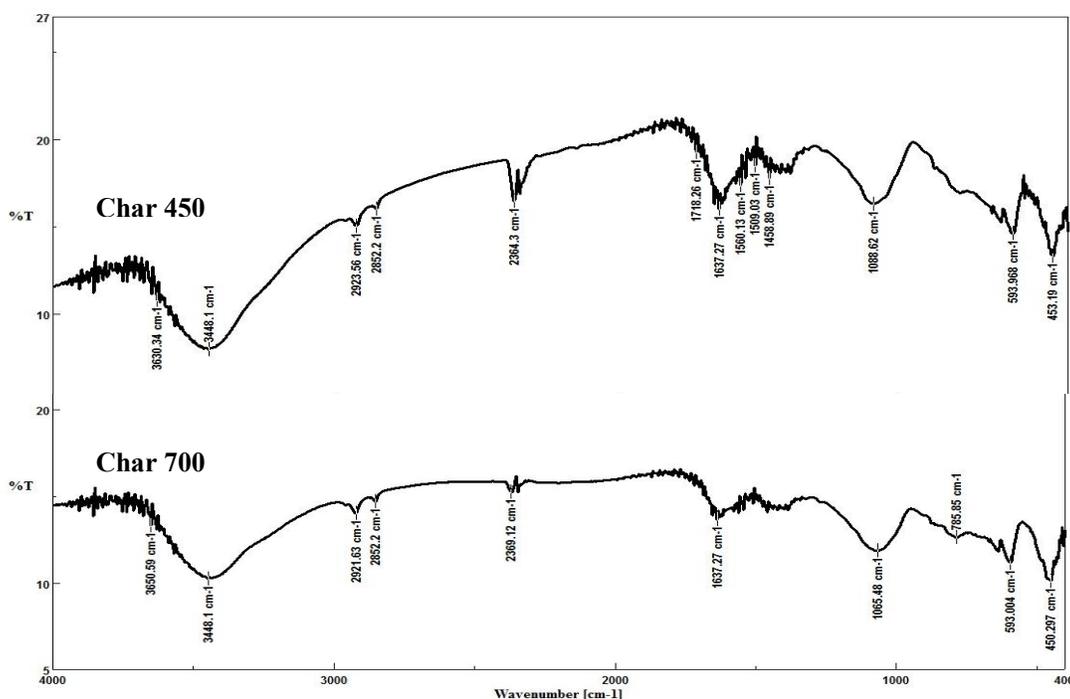
**Table 1. Yield, ash content, CEC and some elemental composition of the rice straw derived biochars (Char 450 and Char 700)**

Sorbent	Charring temp.	Yield	Ash	Volatile matter	TC	CEC	Si	Ca	K
	$^{\circ}\text{C}$			%		$\text{cmol kg}^{-1}$			
Char 450	450	34.9	40.7	31.3	28.0	68	34.5	3.2	47.3
Char 700	700	19.4	57.5	19.1	23.5	42	67.4	0.9	115

CEC = cation exchange capacity. TC = total carbon.

Char 450 is the straw materials charred at  $450^{\circ}\text{C}/60\text{ min}$ .

Char 700 is the straw materials heated gradually upto  $700^{\circ}\text{C}/60\text{ min}$ . (see section 2.2)



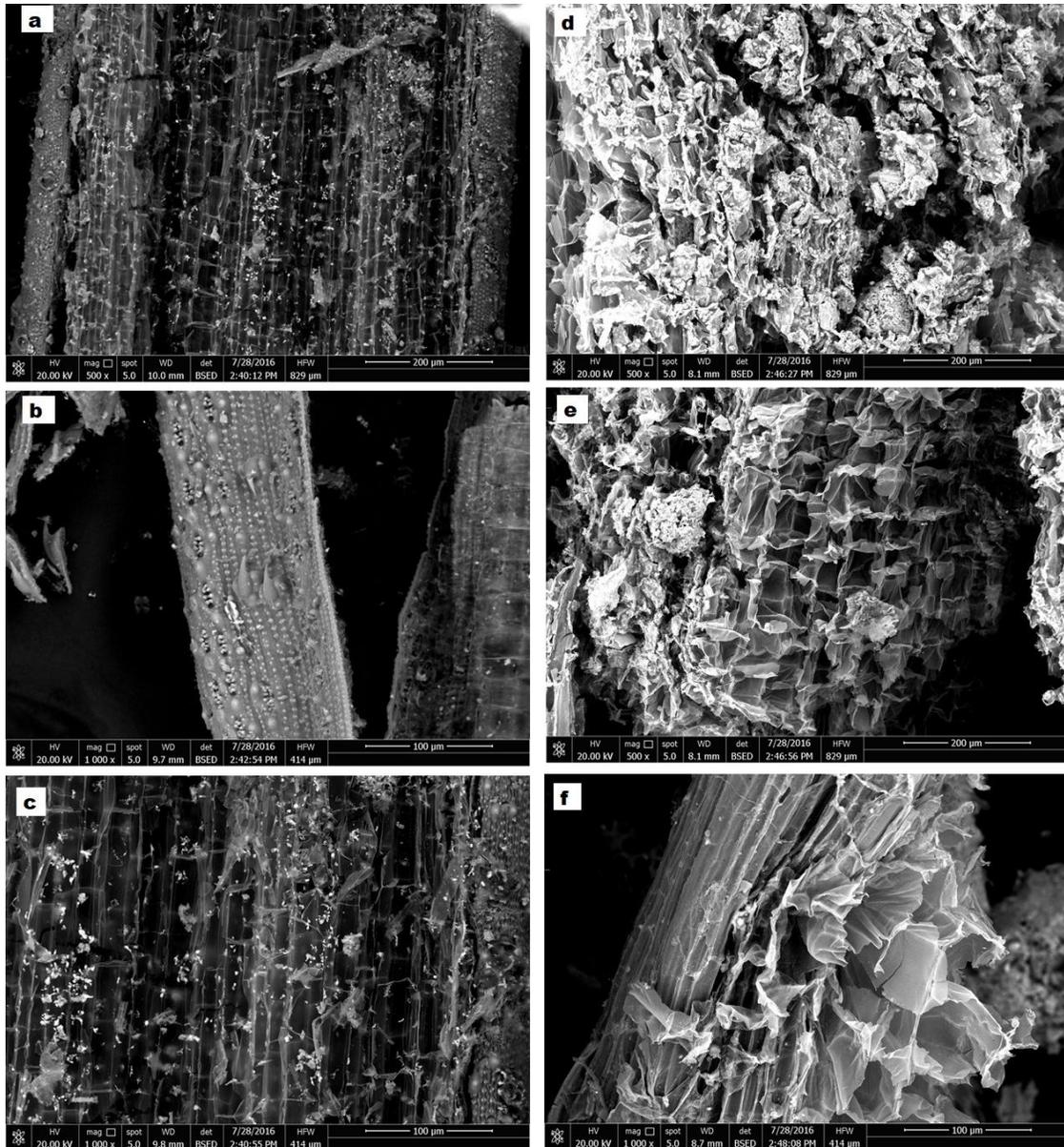
**Fig. 1. FTIR spectra of the rice straw derived biochars generated at different heating treatment (Char 450 and Char 700)**

Char 450 is the straw materials charred at  $450^{\circ}\text{C}/60\text{ min}$ . Char 700 is the straw materials heated gradually upto  $700^{\circ}\text{C}/60\text{ min}$ . (see section 2.2).

Influence of the charring methods on the surface morphologies of rice straw derived biochars showed in Fig. (2 a-f). The images of the scanning electron microscopy (SEM) were obtained at different magnification values. At the lowest charring temperature (Char 450) the images revealed heterogeneities of the surfaces, in which the original cell structure as well as the partially destroyed cells were observed (Fig. 2 a,

b, c). However with the highest temperature (two steps heating treatment; Char 700), the images depicted destruction of the cell walls and exhibited more wide porous structure (Fig. 2 d, e, f).

The morphological changes observed with raising the temperature were in agreement with those reported by other researchers [27].



**Fig. 2. Scanning electron microscopy (SEM) images of the rice straw derived biochars generated at different heating treatment - Char 450 (a, b, c) and Char 700 (d, e, f)**  
 Char 450 is the straw materials charred at 450 °C/60 min. Char 700 is the straw materials heated gradually upto 700 °C/60 (see section 2.2)

### 3.2 Sorption Isotherm

Both biochar materials showed capabilities in the removal of  $\text{Cu}^{2+}$  from aqueous solutions. Generally, the highest sorption were achieved by Char 700. The slow raising of the charring temperature enhanced the sorption abilities of the rice straw derived biochar towards the removal of  $\text{Cu}^{2+}$  ions. This observation was in contrary with that mentioned previously by other investigators [25]. Further, the sorbed amounts of ions were elevated with increasing the initial ion concentrations in the aqueous solutions by different extend until reached saturation states. At low initial concentrations of  $\text{Cu}^{2+}$  (up to  $1.6 \times 10^{-3}$  M), the removal efficiencies of the pollutant reached 96 and 100% by Char 450 and Char 700, respectively. However with increasing the initial concentration of  $\text{Cu}^{2+}$  to  $3 \times 10^{-3}$  M, their removal efficiencies recorded 55 – 66%, respectively.

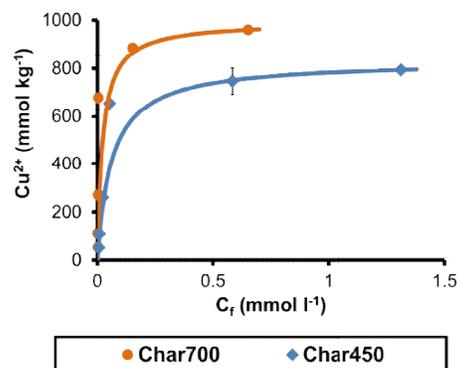
Sorption behaviors of  $\text{Cu}^{2+}$  ions and the fitting models of the sorption data were illustrated in Fig. (3). Sorption isotherm parameters and coefficient of determination ( $R^2$ ) are listed in Table (2). As it is indicated by the  $R^2$  values, Langmuir model is the best model describes the sorption of  $\text{Cu}^{2+}$  compared with Freundlich model. The maximum sorption capacities of  $\text{Cu}^{2+}$  (b) calculated from the Langmuir model recorded 831 and 994  $\text{mmol kg}^{-1}$   $\text{Cu}^{2+}$  for the sorbents Char 450 and Char 700, respectively, which in agreement with the experimental data. The relationship between the separation factors (F) vs. the initial concentrations of  $\text{Cu}^{2+}$  ions are demonstrated in Fig. (4). The F values for both sorbents were less than 1.

At any concentration of the metal ions, the sorption onto Char 700 was more favorable than that by Char 450.

Interestingly with the comparison to other recent study using similar substrate base and at the same initial  $\text{Cu}^{2+}$  concentration ( $3 \times 10^{-3}$  M) [25], remarkable sorption of the metal ions are pronounced from the current experimental data and/or by the estimated values from the mathematical model, reached two fold higher. Thus is highlighting the importance of the treatments and methods involved in the preparation of biochars.

Furthermore, exchangeable processes or binding of metal ions with different functional groups that possessed on surfaces of the charred materials could be the suggested sorption mechanisms of

the  $\text{Cu}^{2+}$  ions [28], which might be confirmed by the measured pH values of the aqueous solutions at equilibrium (pH of final solution in this study are 5.5, not shown data).



**Fig. 3. Sorption isotherm of  $\text{Cu}^{2+}$  onto Char 450 and Char 700. Solid lines represent Langmuir model. Symbols show the mean of measured data of two replicates. Bars represent means  $\pm$  Standard errors;  $n = 2$ .**

$C_f$ : the final concentration of  $\text{Cu}^{2+}$  ions in the solution, Char 450 is the straw materials charred at  $450^\circ\text{C}/60$  min. Char 700 is the straw materials heated gradually upto  $700^\circ\text{C}/60$  (see section 2.2)

**Table 2. Parameters of Freundlich and Langmuir isotherm models resulted from the sorption of  $\text{Cu}^{2+}$  ions onto the rice straw derived biochars (Char 450 and Char 700)**

Model parameter	Char 450	Char 700
<b>Freundlich:</b>		
$K_f$ ( $\text{mmol kg}^{-1}$ )	1012	1410
$1/n$	0.460	0.361
$R^2$	0.745	0.525
<b>Langmuir:</b>		
$K$ ( $\text{l mmol}^{-1}$ )	15.9	44.0
$b$ ( $\text{mmol kg}^{-1}$ )	831	994
$R^2$	0.996	0.993

$K_f$  and  $1/n$  are the sorption capacity and intensity of Freundlich model, respectively.

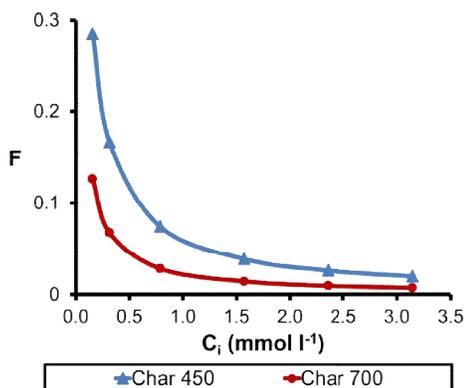
$b$  and  $k$  are the maximum sorption capacity and the Langmuir affinity constant, respectively.

$R^2$  is coefficient of determination. Char 450 is the straw materials charred at  $450^\circ\text{C}/60$  min. Char 700 is the straw materials heated gradually upto  $700^\circ\text{C}/60$  (see section 2.2).

### 3.3 Sorption Kinetic

In the kinetic experiments, sorption of  $\text{Cu}^{2+}$  onto the prepared biochars at two initial concentrations of the metal ions ( $0.5$  and  $2.0 \times 10^{-3}$  M) were investigated. The relationships between the time intervals (T) against the sorbed

amounts as well as the removal percentages of  $\text{Cu}^{2+}$  ions by the rice straw derived biochars (Char 450 and Char 700) are depicted in Fig. (5a) and (5b), respectively. Generally, sorption of the metal ions were increased with time.



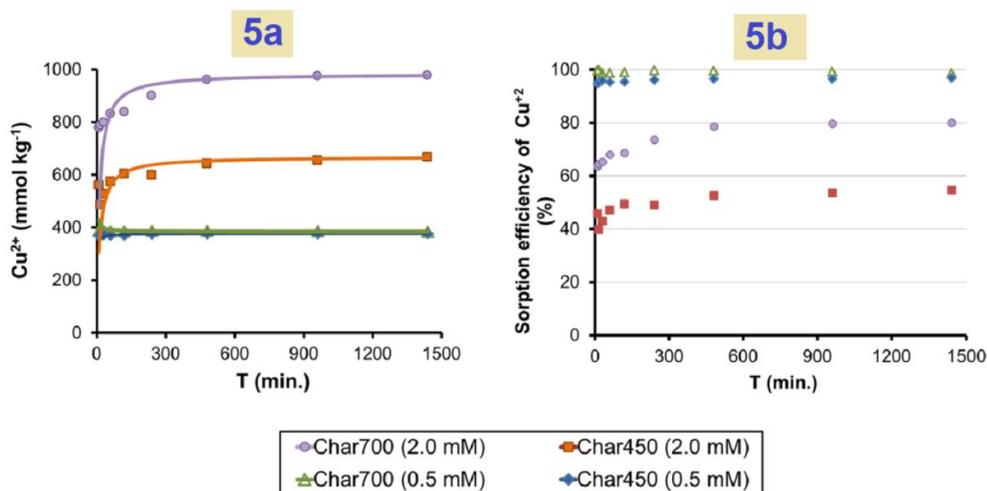
**Fig. 4. Calculated separation factors (F) vs. initial concentrations of  $\text{Cu}^{2+}$  ions ( $C_i$ )**

Char 450 is the straw materials charred at 450 °C/60 min. Char 700 is the straw materials heated gradually upto 700°C/60 (see section 2.2).

At  $0.5 \times 10^{-3}$  M  $\text{Cu}^{2+}$ , both sorbents were able to remove all pollutants from the aqueous solutions approximately within 15 min. of contacting time. Whereas different analogous were obtained with

increasing the pollutant concentrations. At  $2.0 \times 10^{-3}$  M of  $\text{Cu}^{2+}$ , the removal percentages of the ions reached to 50 and 69% by Char 450 and Char 700, respectively, within 2 hours. While the equilibrium were approached after 8 hours of contacting time, achieving 53 and 79% removal of the initial ions concentrations by Char 450 and Char 700, respectively.

Pseudo first and second order kinetic models were tested to describe the sorption data of  $\text{Cu}^{2+}$  onto the biochars within the time intervals. The deviations of the sorption values estimated via the Lagergren equation than those from the experimental data (not shown data), in addition to the low resultant coefficient of determination ( $R^2$ ) values are confirming that the pseudo first order kinetic model is inappropriate for expressing the sorption process of  $\text{Cu}^{2+}$  onto the prepared biochars. The data are better characterized by the pseudo second order kinetic models, that proven by the values of  $R^2$  that is close to 1 and by the reliability of the estimated values ( $q_e$  calculated) with these obtained via the sorption experiments ( $q_e$  exp.; Table. 3). Aforementioned was true with all the sorbents used in the study and at both concentrations of the metal ions, suggesting that the sorption might be controlled by the chemisorptions processes [22,29].



**Fig. 5. Time course (T) of the sorption of  $\text{Cu}^{2+}$  ions ( $\text{mmol kg}^{-1}$ ) and the removal efficiency (%) by the rice straw derived biochars (Char 450 and Char 700) at two initial metal concentrations ( $0.5$  and  $2.0 \times 10^{-3}$  M).**

Char 450 is the straw materials charred at 450 °C/60 min. Char 700 is the straw materials heated gradually upto 700 °C/60 (see section 2.2).

**Table 3. Parameters of the pseudo-second-order kinetic model for Cu<sup>2+</sup> sorption onto Char 450 and Char 700 at two initial concentrations of the metal ions**

Sorbent Parameters	Char 450		Char 700	
	C initial conc. (M)			
	0.5x10 <sup>-3</sup>	2.0x10 <sup>-3</sup>	0.5 x10 <sup>-3</sup>	2.0 x10 <sup>-3</sup>
q <sub>e, exp</sub> (mmol kg <sup>-1</sup> )	377	669	384	978
q <sub>e Calculated</sub> (mmol kg <sup>-1</sup> )	377	664	385	977
K <sub>2</sub> (kg mmol <sup>-1</sup> min <sup>-1</sup> )	0.00264	0.000125	-0.00255	0.000095
R <sup>2</sup>	0.999995	0.9997	0.99998	0.9998

*q<sub>e exp</sub> and q<sub>e calculated</sub> are the measured and the estimated sorbed amounts of metal ions at equilibrium, respectively. k<sub>2</sub> and R<sup>2</sup> are the pseudo-second order rate constant and coefficient of determinations, respectively. Char 450 is the straw materials charred at 450 °C/60 min. Char 700 is the straw materials heated gradually upto 700 °C/60 (see section 2.2).*

#### 4. CONCLUSIONS

The current investigation entails the importance and impact of the charring procedure on the characteristics of derived biochar materials, which depicted by the following:

- Rising the charring temperature at slow rate led to destroy the cells wall and enhancing the porous structure of the rice straw materials in comparison with that prepared at low charring temperature as articulated from the image of the SEM.
- Additionally, increasing the charring temperature improved the sorption efficacy of the produced biochar as elucidated by higher sorption of Cu<sup>2+</sup> onto char 700 (achieving 66% of total ions) than that obtained by Char 450 (55% of metal ions) from aqueous solution of 3x10<sup>-3</sup> M of Cu<sup>2+</sup> ions.

Moreover, differentiations in the removal capabilities of the produced biochars were pronounced with the changing of pollutant initial concentrations and/or with different reaction time. In which, the biochars were able to remove all Cu<sup>2+</sup> ions from the aqueous solution within 15 min at the low initial concentration of the metal ions. Although, these abilities showed different percentages with increasing the initial ion concentrations.

Further investigations are needed to test the potentiality of the prepared biochars towards the removal of different pollutants types from natural wastewater

#### COMPETING INTERESTS

Author has declared that no competing interests exist.

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