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Development and Utilization of Chitosan/Carbon Nanocomposite for Heavy Metal Removal from Wastewater

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Abstract

Industrial or sanitary wastewater, which is rich in heavy elements, represents one of the most important environmental pollutants facing researchers. So, they are working to fabricate environmentally friendly polymers that have a high ability to absorb heavy elements. Chitosan (Cs) is a natural biopolymer that was obtained from shrimp shells using four stages deproteinization, demineralization, decoloration, and deacetylation. In addition, carbon nanoparticles (C-NPs) that were obtained from the treatment of the agriculture wastes were used with the Cs to prepare Cs/C-NPs nanocomposite (Cs/C-NC). Both the prepared Cs and Cs/C-NC were used in water treatment for metal ions (Cr, Cu, Zn, Ni, Cd, and Pb) removal. Fourier Transform Infrared Spectroscopy (FTIR), transmission electron microscope (TEM), and XRD were used to characterize the prepared adsorbents. The adsorption of heavy metals by the prepared samples was investigated as well as the kinetic and isotherm studies. The results exhibited that the quantity of the heavy metals ions uptake by Cs/C-NC was higher than Chitosan alone. Furthermore, the adsorption of various ions with the aid of Cs and Cs/C-NC was examined within varied parameters. Additionally, the kinetic studies of the absorption of Cs and Cs/C-NC for various ions obey Pseudo-second-order. Moreover, the isotherm studies obey Langmuir isotherm for Cs whereas obey Freundlich isotherm for Cs/C-NC except for Zn ions that obey Langmuir isotherm.

Keywords: Chitosan, Shrimp shells, Adsorption, heavy metal, carbon nanoparticles, TEM, SEM, Wastewater

1. Introduction

Water which covers more than 70% of the earth's surface is the most important natural resource of life. It is one of the most crucial resources for all living organism activities [1, 2]. Human activities such as the liberation of unprocessed sewage and industrial water to the environment lead to contamination of different water sources by heavy metals [3-6]. Metal-containing wastes are produced by a variety of industrial operations. The elements such as copper, nickel, chromium, lead, zinc, and cadmium are widely employed in several sectors for various reasons which are released into the environment as a result of industrial wastes [7, 8]. So, heavy metal contamination has become a major issue. As a result of the high solubility of these heavy metals, they are certainly entering the aquatic ecosystems and so build up in living tissues up the food chain and so the food system of humans[9, 10]. Treatment of wastewater is a necessary step in purifying industrial and agricultural wastewater before discharge. So, the preparation of adsorbents for a low-cost and easily made water filtration system is both social and economic [11-14].

Chitosan is one of the most abounded eco-friendly biopolymers and can be used as a good adsorbent of metal. It is prepared by deacetylation of chitin, which is extracted from crustaceans such as shrimp and lobster [15, 16].On account of its abundance and low cost, as well as adsorption capacity, they have gotten

a lot of attention in the water and wastewater treatment industry in recent years [17, 18]. Chitosan-based materials have recently shown amazing potential for efficient adsorption of heavy metals because they are rich in amino and hydroxyl groups [19, 20].

Otherwise, agricultural waste is one of the most important causes of environmental pollution[21], while these wastes are rich in many materials that can be used in the preparation of cellulose compounds, biochar or some elements [22, 23]. Besides that, it can also be used in biogas production as well as the preparation of biochar, which has many agricultural or industrial uses [24-26].

Herein, the chitosan was prepared from shrimp shells, also the carbon nanoparticles were obtained from agricultural wastes via the handling of the production of the pyrolysis of tree trim. In addition, the nanocomposite from chitosan and carbon nanoparticles was prepared. Moreover, the effect of the prepared Cs and Cs/C-NC on the absorption of Cr, Cu, Zn, Ni, Cd, and Pb ions under various parameters from contact time, adsorbents dose, and ions concentration were studied.

2. Material and method

2.1. Raw materials and Chemicals

All the chemicals were of analytical grade and were used without further purification. Sodium hydroxide (NaOH), Nitric acid (HNO₃), and hydrochloric acid (HCl) were obtained from S.D fine chemical Comp. Shrimp shells were taken from the El-Monib local fish market.

2.2. Instrumentation

Fourier transforms infrared spectroscopy (FTIR) was carried out employing the KBr method on a Mattson 5000 spectrometer (Unicam, UK). A transmission electron microscope (TEM; model JEM-1230, Japan) was utilized to study the morphological and particle size of Cs and C-NPS. The XRD pattern of C-NPs was achieved from a Diano X-ray diffractometer using a CoKα radiation source energized at 45 kV and a Philips X-ray diffractometer (PW 1930 generator, PW 1820 goniometer) with a CuK radiation source (λ= 0.15418 nm).

All metals measurements were performed using the Agilent microwave plasma atomic emission spectrometry (MP-AES) model 4200 MP-AES with nitrogen gas plasma supplied via an Agilent 4107 Nitrogen Generator. The Limit of Detection (LOD) and Limit of Quantification (LOQ) of the different heavy metals under studies were illustrated in **Table 1.** The generator alleviates the need and expense of sourcing analytical grade gases. The sample introduction system comprised a double-pass cyclonic spray chamber and the OneNeb nebulizer. The MP-AES features a second-generation

waveguide and torch, with mass flow controlled nebulizer gas flow[27].

Table 1: LOD (=3X standard deviation of 10 measurements in the blank matrix) and LOQ (= 3XLOD) of metals determined in spices.

Element	LOD (µg/mL)	LOQ (µg/mL)
Cd	2.100 X10-3	7.000X10-3
Cr	0.100 X10-3	0.333 X10-3
Cu	0.700 X10-3	2.333 X10-3
Ni	0.900 X10-3	3.000 X10-3
Pb	3.300 X10-3	0.011
Zn	4.500 X10-3	0.015

2.3. Preparation of Chitosan from shrimp shell

A known weight of shrimp shells was washed many times with running tap water to remove dust and soluble impurities and then kept in an oven at 70 °C till became crispy. After drying, a grinding mill was used for crushing the particles and sieved by a 0.2 mm sieve to ensure uniform particle sizes. The production of chitosan from the powdered shrimp shells was carried out through four main stages [28]:

2.3.1. Deproteninization:

Shrimp shells powder (1:10, w/v) was boiled in 3 % NaOH solution for 1h then washed with water until the pH become neutral. After that, it was filtrated and dried at 80 °C till constant weight to obtain a deproteinized powder of shrimp shells.

2.3.2. Demineralization:

Deproteinized powder was mixed with 1N HCl solution (1:15, w/v) at 80 °C for 5 hrs. After heating, the mixture was allowed to cool and settle then filtered and washed with deionized water till neutral pH. After that, it was filtrated and dried at 80 °C till constant weight to obtain shrimp shells powder-free from protein and minerals.

2.3.3. Decoloration

The obtained powder from the previous steps was washed carefully to remove any color to obtain chitin.

2.3.4. Deacetylation

In this process, the chitin was converted to chitosan by removing the acetyl group. The chitin (1:10, w/v) was treated with 0.5M of NaOH solution for 2 hrs. at 100 °C, then the mixture was allowed to cool and settle followed by filtration and washing with deionized water to neutral pH, thereafter, the residues were oven-dried at 80 °C for 45 minutes to obtain chitosan.

2.4. Preparation of carbon nanoparticles (C-NPs)

The agricultural wastes obtained from tree trim were pyrolysis at 350 ºC in the absence of air to produce the biochar [29]. The obtained biochar was ground to a fine powder and sieved with a 400 mesh sieve. After that, the biochar powder was treated with

nitric acid (HNO_3; 1N), followed by distilled water till neutral pH. The collected powder was dispersed in water and then left to settle down where the upper part containing floating carbon nanoparticles (CNPs) was taken. The latter step was reduplicated three times to ensure that the solution contained only CNPs [30]. The floating solution containing CNPs has centrifuged at 10000 rpm for 20 min then the wet powder was dried at 60°C for 24 h to get CNPs.

2.5. Preparation of the nanocomposite of Cs/C-NPs nanocomposite (Cs/C-NC)

A certain amount of chitosan (2 g) was dissolved in 1% acetic acid solution after that 0.02 g of C-NPs under stirring for 1h. The previous solution was drying using Freeze-dryer to get Cs/C-NC.

2.6 Sorption study

2.6.1 Effect of sorbents dose

The efficiency of the adsorbent doses by adding (0.125, 0.25, 0.5, and 1 g/l) of Cs and Cs/C-NC for removal of 100 mg/l of various heavy metals (Cr, Cu, Zn, Ni, Cd, and Pb) were evaluated. The solutions were filtered and the remaining heavy metals ions concentration was measured by MPAES (model 4200 MP-AES). The removal efficiency percent (R%) of the sorbents was calculated by the following equation:

$$R = \left(\frac{C_0 - C_t}{C_0}\right) * 100 \quad \text{.................. (Eq. 1)}$$

Where; C_0: the initial ions concentration (mg/l), C_t: the remaining ions concentration after a period of time (t) (mg/l), V: volume of solution (ml).

2.6.2. Effect of contact time on the removal efficiency of heavy metals ions

The removal efficiency of different heavy metals from 100 ml aqueous solutions by the Cs and Cs/C-NC was studied at various time intervals (15–360 min) at pH = 6 using 1 g/l of sorbent and 100 mg/l of heavy metals ions. The removal efficiency percent (R%) was calculated from equation (1). The amount of the heavy metals ions uptake (q) within the adsorbent was calculated by the following equation:

$$q = (C_0 - C_t)x \frac{V}{M} \quad \text{.................... (Eq. 2)}$$

Where; Co is the initial heavy metals ions concentration (mg/l), C_t is the remaining heavy metals ions concentration after a time (t) (mg/l), V is the volume of solution (ml), and M is the mass of the adsorbent added (g).

2.7.3. Effect of the concentration of various metal ions on removal efficiency and uptake capacity

The R% and q were calculated for the prepared absorbents at different concentrations of various heavy metals ions (10, 30, 50, 100, and 150 mg/l) were investigated at the time 120 min and pH 6.

2.7.4. Kinetic and Isotherm Study

The kinetic models using pseudo-first-order [31] and pseudo-second-order [32] were used to demonstrate the sorption rate constants of different heavy metals (Cr, Cu, Zn, Ni, Cd, and Pb). Also, the adsorption isotherms using Langmuir [33] and Freundlich [34] were applied to study how the heavy metals interact with the sorbent (Cs and Cs/C-NC). The equations and constants of the kinetic and isotherms models were itemized in **Table 2.**

Table 2: Kinetics models and Isotherms models for the removal of tramadol onto sorbents:

Kinetics Models				
Models	**Equations**	**Variables**	**Graph**	**Remarks**
Pseudo-first-order	$Log\ (q_e - q_t) = log q_e - (k_1/2.303)\ t$ *Where;* $q_t = (C_0 - C_t) * (V/M)$	q_e:equilibrium sorption capacity (mg/g) q_t:capacity of sorption (mg/g) at a time (t, min) k_1 : the rate constant (min^{-1}) V: volume of solution (L) M: mass of the sorbent added (g)	log ($q_e - q_t$) Vs t	------
Pseudo-second-order	$t/q_t = 1/k_2 q_e + (1/q_e)\ t$	k_2: the rate constant (g/mg. min)	t/q_t Vs t	------
Isotherms Models				
Langmuir isotherm	$C_e/q_e = 1/bq_{max} + (1/q_{max})\ C_e$ $R_L = 1/(1+bC_0)$	b: the Langmuir constant (l/mg) q_{max}: the maximum sorption capacity (mg/g) R_L : separation factor	C_e/q_e Vs C_e	R_L= 1: shows linear adsorption R_L = 0: illustrates irreversible R_L> 1: represents unfavorable adsorption 0<R_L< 1 : indicated good adsorption
Freundlich isotherm	$ln q_e = ln k_f + (1/n)\ ln C_e$	k_f: the Freundlich constant n: the strength of adsorption	$ln\ q_e$ Vs $ln\ C_e$	n=1: characterizes linear adsorption n<1: represents the chemical process n>1: designates the physical process

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3. Result and discussion

3.1 Characterizations

Figure 1 illustrated the transmission electron microscope image, X-ray diffraction patron, and infrared spectrum of the prepared carbon nanoparticles. **Fig. 1a** illustrated the spherical shapes of the prepared carbon nanoparticles which have narrow size distribution and the majority of particles size was less than 100 nm. **Fig. 1b** showed the XRD patron of the prepared carbon nanoparticles (CNPs) which demonstrated the diffraction peaks at $2\theta = 24.6$, 44.7, and 76.7 corresponding to (0 0 2), (1 0 0), and (1 1 0) of C-NPs, respectively, [35, 36], which indicates the preparation of CNPs in the pure form from the pyrolysis of tree trim.
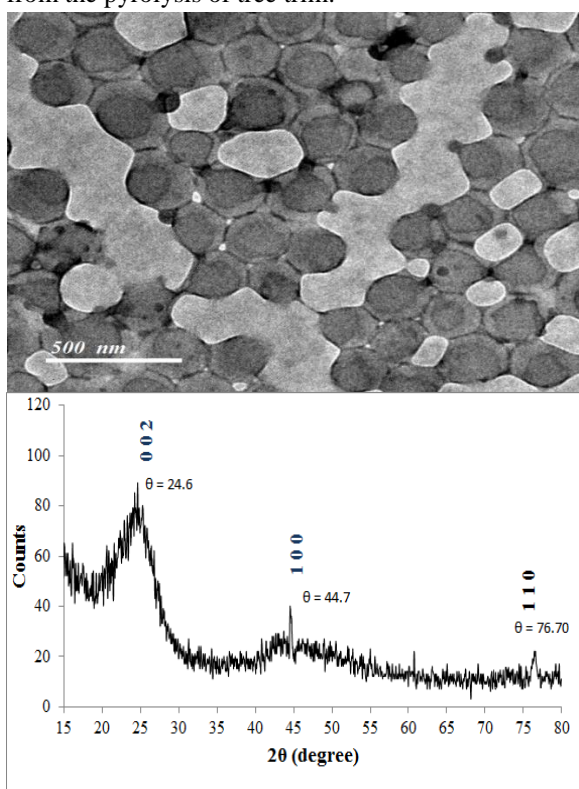

Fig. 1: TEM (a) and XRD (b) of the prepared C-NPs

The FT-IR spectrum of the Cs, C-NPs, beside the synthesized Cs/C-NC was illustrated in **Fig. 2**. The pure Cs have a broad band between 3500 to 3100 cm^{-1} corresponding to O-H and N-H stretching, as well as the basic characteristic bands at 1650, 1440, and 1075 cm^{-1} are related to N-H and C-O-H bending, and C-O-C stretching, respectively[37]. Also, **Fig. 2** showed the characteristic bands at 1600, 1430 and 1050 cm are due to the stretching and bending of C–H, as well as C–O stretch, respectively, which

corresponded to carbon nanoparticles[38]. Whilst, the prepared nanocomposite (Cs/C-NC) contains the distinct groups for both chitosan and carbon nanoparticles as shown in **Fig. 2**.
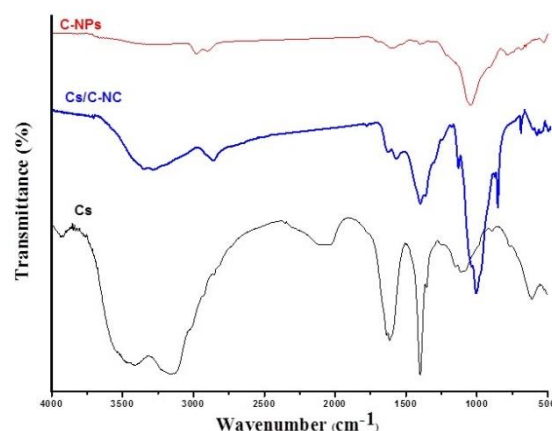

Fig.2: The FT-IR of Cs, C-NPs, and Cs/C-NC.

3.2. Adsorption Study

Different parameters such as contact time, adsorbents dose, and the concentration of heavy metal ions were studied to illustrate the ability of the prepared chitosan (Cs) as well as the nanocomposite of chitosan/carbon-nanoparticles (Cs/C-NC) in the absorption of various heavy metal ions such as Cr, Cu, Zn, Ni, Cd, and Pb. By studying those different parameters, we noticed that Cs/C-NC adsorption capacity is much higher than chitosan, which indicates that the addition of carbon nanoparticles to chitosan improves the ability of the prepared nanocomposite to absorb different ions.

3.2.1. Effect of Contact Time

Figs. 3 (a & b) represented the effect of 0.1 g of Cs and Cs/C-NC, respectively, on the removal percentage of different ions by changing the time from 15 min to 360 min at pH = 6. It was observed that the removal percentage of tested ions increases with the increase of contact time, where it was increased sharply during the first 60 min then slowly from 60 to 240 min until reaching equilibrium at 360 min. The rapid initial adsorption rate may be due to the availability of sufficient vacancies and the high driving force of the ions within the adsorbents which causes the quick transfer mechanism between the adsorbed metal ions and the binding site of the adsorbent[13, 39].

The results showed that the removal percentage of Cd, Cu, Pb, Zn, Cr, and Ni using Cs (**Fig. 3a**) was 36.7, 38.2, 49.0, 51.0, 52.9, and 60.1, respectively,

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which increased by using Cs/C-NC (**Fig. 3b**) to be 87.6, 42.8, 87.1, 94.4, 93.7, and 90.6, respectively. This may be due to the addition of carbon nanoparticles to chitosan improving the removal percentage of tested ions by increasing the active sites that are capable of absorbing ions.
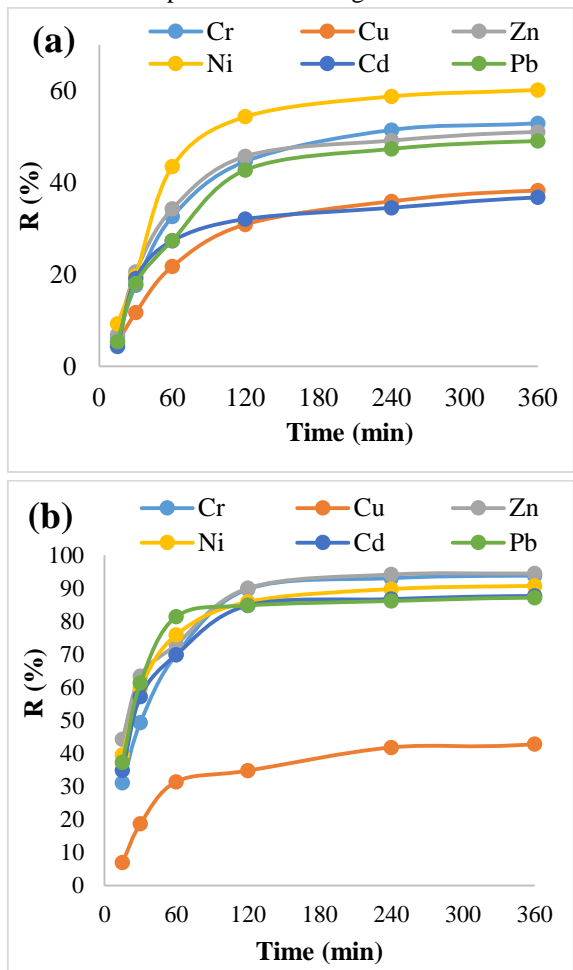

increase of active sites numbers that are available to adsorb ions[40, 41]

The adsorption of Cr, Cu, Zn, Ni, Cd and Pb ions on the chitosan was 8.00, 7.82, 13.86, 20.82, 8.58, and 10.37%, respectively, using a dose of 0.125 g. And it increased by increasing the dose of adsorbent to 47.48, 34.01, 36.86, 49.21, 20.49, and 29.51 %for Cr, Cu, Zn, Ni, Cd, and Pb, respectively, by increasing the dose of chitosan to 1 g as shown in **Fig. 4a**.

An additional increase in the percentage of the removal of metal ions of adsorbent dosage was detected when the same doses were used after adding the activated carbon. The results showed that the removal percentage of metal ions at a dosage of 0.125 g of Cs/C-NC(**Fig. 4b**) were 31.4, 26.3, 41.2, 23.1, 55.7, and 31.42% which increased to be 88.7, 33.6, 89.2, 91.8, 94.4, and 93.6%, for Cr, Cu, Zn, Ni, Cd, and Pb, respectively, by increasing the dosage to 1 gm.
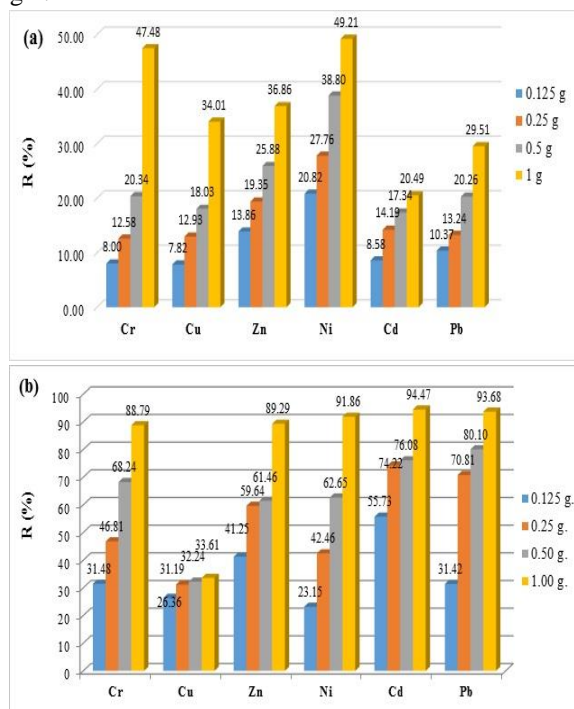

Fig. 3: The removal efficiency (R %) of 30 mg/l various ions by 0.1 g of Cs (a), and Cs/C-NC (b) as a function of contact time (15 – 360 min) at pH = 6.

3.2.2 . Effects of Adsorbent Dose

The dosage of the adsorbent has an important value on the adsorption process and it describes the capacity of the adsorbent through the number of active binding sites accessible to remove heavy metal ions. **Figs. 4** (a & b) illustrated the effect of changing the dose of Cs, and Cs/C-NC from 0.125 to 1 g as well as their uptake capacity for adsorbed of various ions under studies from the solutions at fixed the other parameters (pH = 6, time = 120 min, and ion concentration = 30 mg/l). The adsorption of the ions is observed to increase as the dose of adsorbent is increased from 0.125 to 1 g, which may be due to the

Fig. 4: Effect of Cs (a), and Cs/C-NC (b) dosage on removal efficiency at pH=6 and time 120 min.

3.2.3. Effects of Metal Ions Concentration

The initial concentration of ions played an important role to overcome the transfer resistance of metal ions between the solutions to absorbents [41]. The initial heavy metals ions concentration (Cr, Cu, Zn, Ni, Cd, and Pb) were varied from 10 to 150 mg/l at room temperature, adsorption time of 120 min, and adsorbent mass of 1 g/l. The solution pH of various ions under study was 6. The impact of initial heavy metals ions concentration on the adsorption rate is

shown in **Figs. 5** (a & b) for Cs and Cs/C-NC, respectively.

It was noticed that the removal percentage of various ions using the adsorbents (Cs and Cs/C-NC) was decreased with raise in the initial ions concentration. Moreover, the results showed that using Cs/C-NC was more effective in the removal of metal ions from water samples compared with using Cs. The percentage uptake of Cs/C-NC (**Fig. 5b**) for removal of Cr, Cu, Zn, Ni, Cd, and Pb ions were 59.94, 16.25, 50.32, 66.22, 75.14, and 74.09 %, respectively, compared with using Cs (**Fig. 5a**) which was 22.13, 10.06, 11.50, 17.54, 7.85 and 9.15 %, respectively. This is because the number of active sites, as well as the surface area of different adsorbents, was constant against the increase of the ions in the solution. So, at the lower concentration of ions in the solution the loading capacity of ions in the adsorbent was high and so the residual concentration of ions in the solution was decreased [42, 43].
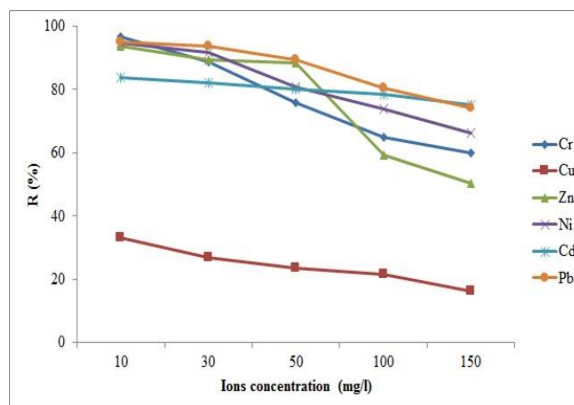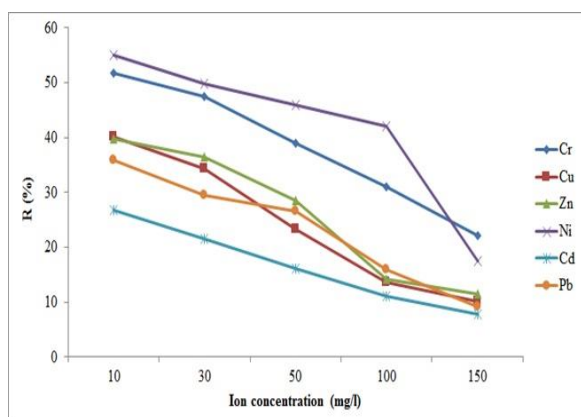

Fig. 5. The removal percentage of various metal ions at different concentrations using Cs (a) and Cs/C-NC (b).

3.3 . Kinetic and Isotherm Study

Two kinetic models (**Table 3**); pseudo-first-order (**Fig. 6**), and pseudo-second-order (**Fig. 7**), and two adsorption isotherms (**Table 4**); Langmuir (**Fig. 8**), and Freundlich (**Fig. 9**) were used to study the kinetics and the interaction between the ions under study and the sorbent.

The kinetics models for the removal of Cr, Cu, Zn, Ni, Cd, and Pb ions onto Cs and Cs/C-NC were illustrated in **Figs. 6&7** and **Table 3**. It can be observed that the absorption study of various ions obeys the pseudo-second-order mechanism, where the sorption rate constants (k) were in the following order: Cd > Zn > Cu > Ni > Cr > Pb for Cs while for Cs/C-NC the order was Pb > Cd > Ni > Zn > Cr > Cu. Also, the sorption rate constant (k) was higher for Cs/C-NC than Cs as shown in **Tables 3** and **Fig**. **7**. Many kinds of literature illustrated that the sorption kinetics studied of divalent metals follow the pseudo-second-order mechanism [4,8,44, 45].

Table 3: The constants of kinetics models for the removal of various ions onto Cs and Cs/C-NPs NC

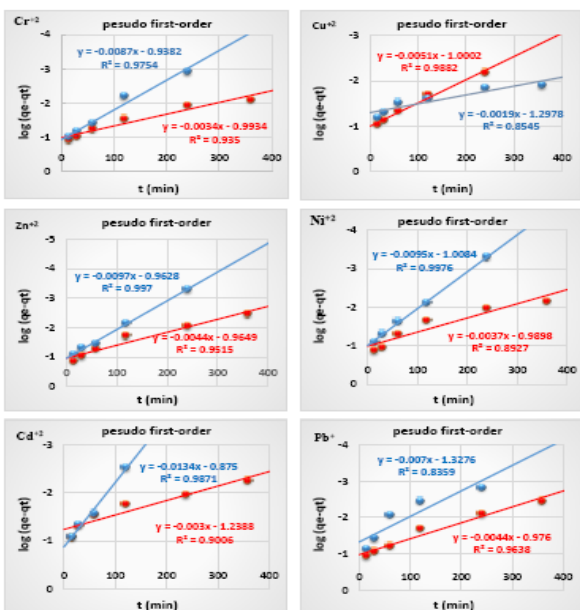|		Pseudo-first-order				Pseudo-second-order			
		K_1 (min^{-1})	q_e(exp.) (mg/g)	q_e (cal.) (mg/g)	R^2	K_2 (g/mg min)	q_e(exp.) (mg/g)	q_e (cal.) (mg/g)	R^2
Cr^{2+}	Cs	0.008	0.13	0.1	**0.9350**	0.08	0.13	0.15	**0.9832**
	Cs/C-NC	0.02	0.15	0.12	**0.9754**	0.27	0.15	0.15	**0.9985**
Cu^{2+}	Cs	0.01	0.11	0.1	**0.9882**	0.1	0.11	0.12	**0.9887**
	Cs/C-NC	0.004	0.076	0.05	**0.8545**	0.16	0.076	0.08	**0.9872**
Zn^{2+}	Cs	0.01	0.15	0.1	**0.9515**	0.1	0.15	0.17	**0.9847**
	Cs/C-NC	0.02	0.148	0.11	**0.9970**	0.43	0.148	0.15	**0.9995**
Ni^{2+}	Cs	0.008	0.16	0.1	**0.8927**	0.09	0.16	0.17	**0.9885**
	Cs/C-NC	0.02	0.141	0.1	**0.9976**	0.44	0.141	0.147	**0.9997**
Cd^{2+}	Cs	0.01	0.095	0.06	**0.9006**	0.14	0.095	0.1	**0.9745**
	Cs/C-NC	0.01	0.1365	0.13	**0.9871**	0.44	0.1365	0.14	**0.9992**
Pb^{2+}	Cs	0.01	0.13	0.1	**0.9638**	0.08	0.13	0.15	**0.9743**
	Cs/C-NC	0.01	0.128	0.05	**0.8359**	0.64	0.128	0.13	**0.9994**

Fig. 6 Pseudo-first-order models for the removal of Cr, Cu, Zn, Ni, Cd, and Pb ions onto Cs (Red) and Cs/C-NC (Blue)
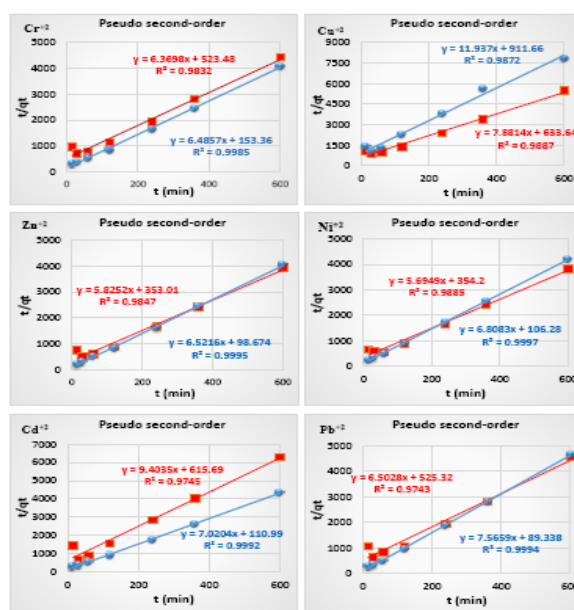
Fig. 7 Pseudo second-order models for the removal of Cr, Cu, Zn, Ni, Cd, and Pb ions onto Cs (Red) and Cs/C-NC (Blue)

The equilibrium between the various metal ions removal and the adsorbent surface (Cs and Cs/C-NC) was studied to determine the sorption isotherm (**Figs. 8 & 9**). Where the data obtained from equilibrium isotherm using various isotherm models give important knowledge about the mechanisms of adsorption as well as the adsorbent surface properties

and the relationship between solution and the adsorbent. Langmuir and Freundlich's models were used to investigate the isotherm adsorption of various ions and the prepared adsorbents. The initial ions concentration was varied from 10 to 150 mg/l as shown in **Figs. 3-4**. The parameters results of Langmuir and Freundlich are watched in **Table 4**.
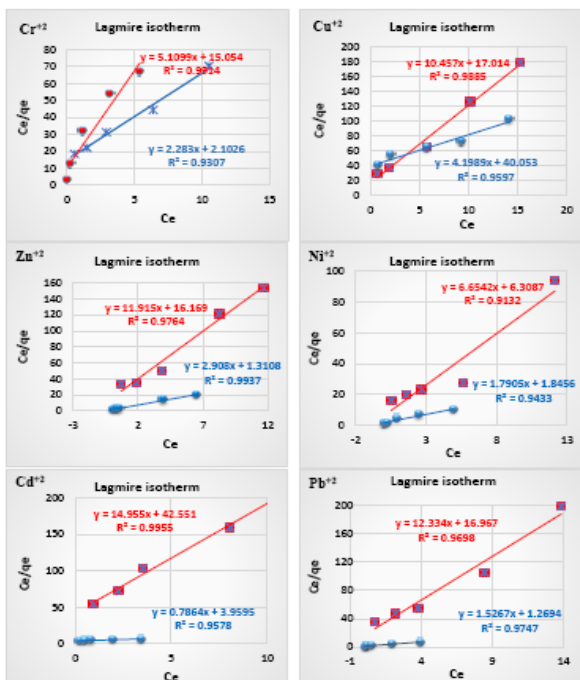

Fig. 8 Langmuir isotherm models for the removal of Cr, Cu, Zn, Ni, Cd, and Pb ions onto Cs (Red) and Cs/C-NC (Blue)
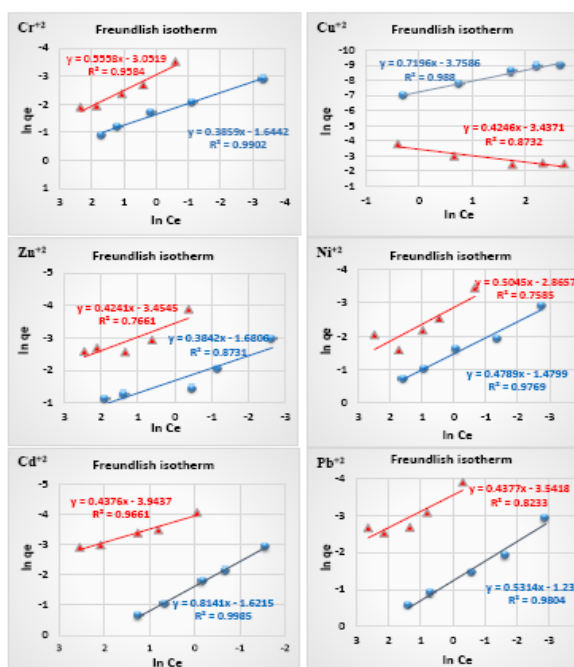
Fig. 9 Freundlich isotherm models for the removal of Cr, Cu, Zn, Ni, Cd, and Pb ions onto Cs (Red) and Cs/C-NC (Blue)

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The results showed that adsorbent Cs provided the best fit with the Langmuir model. This proposes that the fixation of various ions under study is done in a monolayer, and on energetically equivalent sites (homogenous sites) without interaction between the adsorbed molecules. Iqbal et al [46] illustrated that the adsorption of Cd^{2+} and Pb^{2+} from aqueous solutions using mango peel waste fitted the Langmuir isotherm models. Even though, the Freundlich model provides the best fit for the sorption of different ions under study using Cs/C-NC adsorbent which represented multilayer adsorption onto the heterogeneous surface [47]. This may be due to the presence of two phases consisting of carbon nanoparticles and chitosan in the prepared Cs/C-NC. Lingamdinne et al. [48] illustrated that the adsorption of Co ions from aqueous solutions using graphene oxide fitted the Freundlich isotherm models.

Table 4: The constants of isotherms models for the removal of various ions onto Cs and Cs/C-NC

		Langmuir isotherm			Freundlich isotherm		
		q_{max}(mg/g)	b (l/mg)	R^2	n	K_f	R^2
Cr^{2+}	Cs	0.2	0.3	**0.9914**	1.8	0.05	**0.9584**
	Cs/C-NC	0.44	1.1	**0.9307**	2.6	0.19	**0.9902**
Cu^{2+}	Cs	0.1	0.6	**0.9885**	2.4	0.03	**0.8732**
	Cs/C- NC	0.24	0.1	**0.9597**	1.39	0.02	**0.9880**
Zn^{2+}	Cs	0.08	0.74	**0.9764**	2.3	0.03	**0.7661**
	Cs/C-NC	0.24	2.2	**0.9937**	2.6	0.18	**0.8731**
Ni^{2+}	Cs	0.15	1	**0.9132**	2	0.06	**0.7585**
	Cs/C-NC	0.56	0.97	**0.9433**	2.1	0.23	**0.9769**
Cd^{2+}	Cs	0.07	0.3	**0.9955**	2.3	0.02	**0.9661**
	Cs/C-NC	1.27	0.2	**0.9578**	0.81	0.2	**0.9985**
Pb^{2+}	Cs	0.08	0.7	**0.9698**	2.3	0.03	**0.8233**
	Cs/C-NC	1.27	1.2	**0.9747**	1.88	0.29	**0.9804**

Conclusion

Chitosan and carbon nanoparticles were prepared successfully from shrimp shells and agricultural wastes, respectively. Also, the nanocomposite of chitosan/carbon nanoparticles was synthesized. Furthermore, the absorption studies of Cs and Cs/C-NC for Cr, Cu, Zn, Ni, Cd, and Pb were investigated as well as the kinetic and isotherm studies were performed. The results showed that the prepared carbon nanoparticles have particles size less than 100nm. In addition, the removal percentage for Cr, Cu, Zn, Ni, Cd, and Pb using Cs/C-NC is higher than Cs. Besides that, the absorption of Cs and Cs/C-NC for various ions obeys Pseudo-second-order. While the isotherm study for Cs obeys Langmuir isotherm whereas Cs/C-NC obeys Freundlich isotherm.

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