

ADSORPTION OF LEAD (II) IONS FROM SYNTHETIC WASTEWATER USING COCONUT SHELL CARBONS ACTIVATED BY NaOH

Eman J. YOUNOS¹

University of Baghdad, Iraq

Nuralhuda Aladdin JASIM²

Wasit University, Iraq

Hamsa Natiq FADHIL³

University of Baghdad, Iraq

Abstract

In this study, Carbons made from coconut shells that were activated with NaOH used to remove Pb (II) from aqueous solutions. SEM was used to analyze the structure and porous morphology of coconut shell carbons. Adsorption behavior was also investigated, as are the conservation equations and kinetics of sorption on carbons synthesized from coconut shells, as well as the impacts of adsorbent dose, agitation time, and starting concentration level. The findings demonstrate that the formation of rich porous structures was promoted by a material containing an appropriate weight percentage of NaOH. When it came to remove Pb (II) from aqueous solutions, the adsorbent produced from coconut shells had a significant specific surface area of 1550 m²/g and a high adsorptive capacity. According to kinetic data, pseudo-second-order kinetic models best represent adsorption. After intra-particle diffusion and external diffusion, this happened during the adsorption process.

Keywords: *Activated carbon, porous, isothermal, adsorption, and coconut shell carbons.*

Introduction

Due to their extreme toxicity, the propensity to cluster in local producers, and extended half-lives in ecosystems, heavy metals constitute a major hazard to human and environmental health [1]. Pb(II), a heavy metal produced during the production of batteries, ceramics, and glass, is one of these metals. The respiratory system, lungs, reproductive system, hepatic system, and mind have all been related to serious threats during the metals planting, polishing, publishing, and leading manufacturing processes [2,3]. Since lead does not disintegrate in the environment the same way as organic contaminants do, businesses

 <http://dx.doi.org/10.47832/2717-8234.17.13>

¹  e.younos1211@coeng.uobaghdad.edu.iq

²  njasim@uowasit.edu.iq

³  hamsa.natiq.187@coeng.uobaghdad.edu.iq



and environmentalists struggle to try and get rid of Pb-containing effluent [4]. Chemisorption, electrolytic reduction, ion exchange, membrane filtration, membrane technology, and adsorption remove Pb(II) from wastewater [6–10].

Because it is rapid and effective at removing pollutants from aqueous solutions, adsorption appears to be the best option when compared to other treatment methods [11]. In addition to their catalytic properties, activated carbons' (ACs), high porosity, huge surface area, and changing surface chemistry make them excellent wastewater and vapour sorbents. However, their application as an adsorbent in developing nations is restricted due to their expensive cost and non-renewable source [12, 13].

By using coconut shell-activated carbons as absorbents in water purification or the rehabilitation of mining and industrial effluents, the value of these agricultural products may be increased while the cost of waste disposal is reduced [14, 15]. This study offers extensive laboratory research on the removal of lead (II) from the aqueous phase utilizing carbon derived from coconut shells as an adsorbent. Several adsorption equilibrium and batch adsorption models were used for the empirical observations. Investigating Pb(II) adsorption activity on coconut shell carbons and evaluating the potential usefulness of this technique for removing hazardous metals from the aqueous phase are the primary aims of this study.

Materials and Approach

1.1 Preparation of the adsorbent

After being rinsed with deionized water, the coconut shells were dried at 150 °C for 30 hours to evaporate any remaining moisture. The test samples were then filtered to a size between 1-2 mm, after being separated. The coconut shells were then calcined for a further two hours at a rate of 20 °C/min, reaching temperatures of 500 °C. A stainless steel beaker was used to carburize the ingredients before they were combined with water and NaOH weighted 1:2 (CSC-A) and 2:1 (CSC-B). After five hours of drying at 130 °C, the combinations were heated to 800°C at 10°C/min.

After being brought to room temperature, they were washed in a solution of hydrochloric acid and deionized water until the pH reached to (6.5-7). BET stands for the Brunauer-Emmett-Teller approach [16] carbons recovered from coconut shells, the SBET was calculated by monitoring nitrogen gas volume across a 0.99 concentration range to obtain the total pore volume (V_T). Coconut shell carbon was analyzed using SEM. (Philips XL30 FEG).

2.2 Preparation of synthetic wastewater

To make the lead stock solution, 16.1 grams of lead nitrate were dissolved in one liter of distilled water. The (100, 200, 300, 400, 600, 900, and 1200) mg/L lead concentrations were used to develop the lead standard.

2.3 Experimental Work

250 mL of Lead(II) combinations were added to coconut shell carbons. The materials were sieved through 0.45 mm after the adsorption processes. According to the established correlation between high ionic conductivity and Pb(II) content, the impedance of the resultant filtrates was measured using a conductivity meter [17]. The adsorption efficiency q_e (mg/g) and the degradation efficiency Q , respectively, were calculated using equations (1) and (2).

$$q_e = \frac{(C_0 - C_e) \cdot V}{W} \quad \text{_____} \quad (1)$$

$$Q = \frac{(C_0 - C_e)}{C_0} \times 100\% \quad \text{_____} \quad (2)$$

Solution volume, V , determines the adsorbent quantity, W . The constants C_0 and C_e are the solution volume and adsorbent weight, respectively.

2.4 Adsorption Isotherm

Langmuir and Freundlich's isotherms were used to study the adsorption of lead (II) by carbons extracted from coconut shells. The Langmuir isotherm and the following formula form are used to depict and characterize monolayer adsorption:

$$\frac{C_e}{q_e} = \frac{1}{q_{\max} b} + \frac{C_e}{q_{\max}} \quad \text{_____} \quad (3)$$

The time-varying non-dimensional constant, R_L , is defined as follows and is used to characterize the fundamental features of the Langmuir isotherm:

$$R_L = \frac{1}{1 + bC_m} \quad \text{_____} \quad (4)$$

where q_e is the equilibrium uptake of heavy metal ions during adsorption and q_{\max} is the maximal monolayer coverage capacity. The initial concentration of heavy metal ions is highest in C_m . The Langmuir constant, or b , and the adsorption energy are connected. The adsorption that takes place on a heterogeneous surface is often controlled by the Freundlich isotherm. This is the linear form.

$$\log q_e = \log K_F + \frac{1}{n} \log C_e \quad \text{_____} \quad (5)$$

where the adsorption strength (K_f) and capacity (n) are Freundlich constants.

2.5 kinetics study

Two kinetic models were investigated to better understand the adsorption dynamics; Pseudo-first-order, pseudo-second-order, and intra-particle diffusion models were used. Linear pseudo-first-order kinetic model.

$$\log(q_e - q_t) = \log q_e - \frac{K_1 t}{2.303} \quad (6)$$

A linear pseudo-second-order kinetic model is employed.:

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{1}{q_e} t \quad (7)$$

q_t is the adsorption quantity at time t , k_1 is the pseudo-first-order kinetic model's adsorption rate constant, and k_2 is the pseudo-second-order model's.

3. Results and Discussions

3.1 Coconut Shell Carbons' Morphology and Pore Structural Characteristics

Figure 1 shows an example of a CSC SEM image. NaOH successfully creates huge holes with a honeycomb structure in coconut shell carbons, as seen by the surface of the material. The high NaOH content of the sample encourages the growth of a more complex porous structure. The ability of activated carbons to produce porosity is closely linked to SBET and V_T . When the NaOH/sample ratio is raised from 0.5 to 2, as shown in Figure 2, The S BET (731–1550 m²/g) and V_T (0.390–0.442 cm³/g) are SEM-compatible.

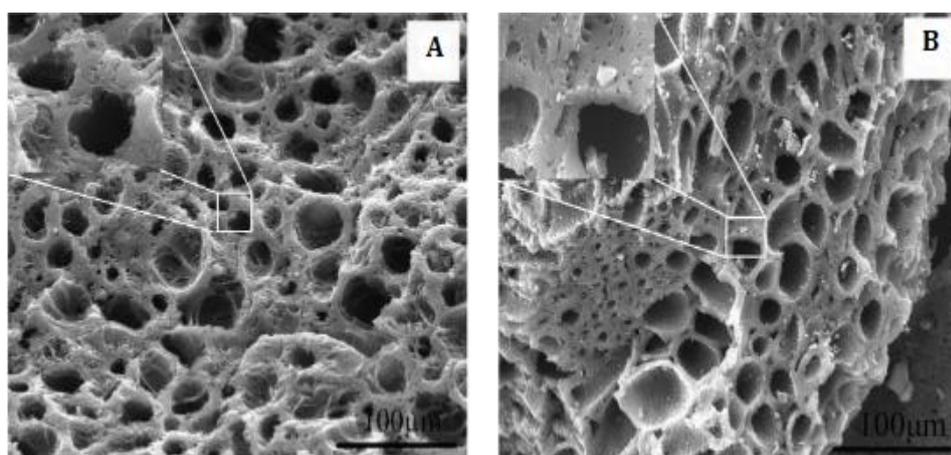


Fig. 1: CSC-A (a) and CSC-B (b) as seen using a scanning electron microscope.

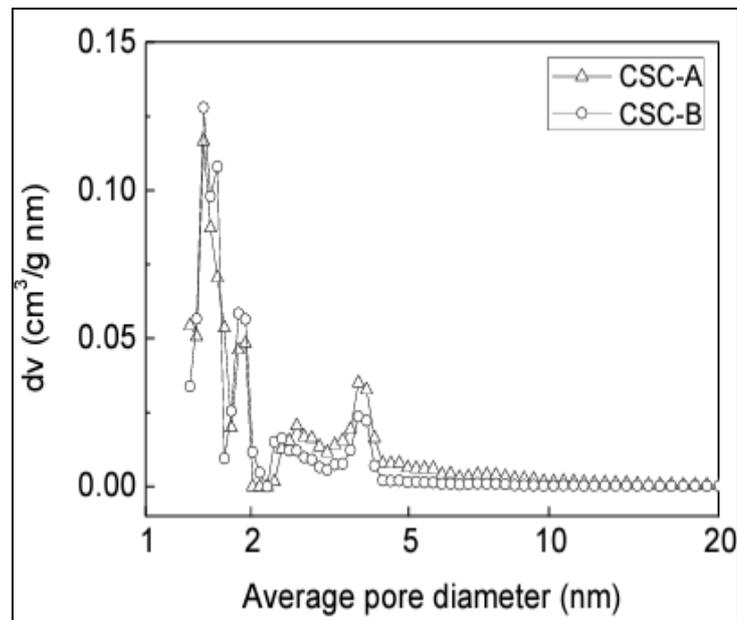


Fig. 2: Carbons from coconut shells, pore size distributions.

3.2 Adsorbent Concentration Affects Lead(II) Disposal

Figure 3 (a&b) show CSC-A and CSC-B lead (II) removal efficiency and adsorption capacity. It's obvious that as the adsorbent concentration rises, so does the efficacy of Pb(II) removal. It's conceivable that more Pb(II) is adsorbed at greater adsorbent concentrations [19]. When the adsorbent concentration stabilizes at 4 g/L, a state of equilibrium has been reached between the adsorbate-bound and free ions [20]. As can be seen in Figure 2, the adsorption capacity for Pb(II) diminishes as the concentration of the adsorbent rises. Because only a fraction of the active sites are filled by lead (II), increasing the concentration of the adsorbent results in a decrease in its adsorption capability, while a lower concentration of adsorbent results in a higher adsorption capacity because more active sites are used. We also highlight the correlation between the adsorbent's S_{BET} and V_T and Pb(II) sorption in aqueous settings [22].

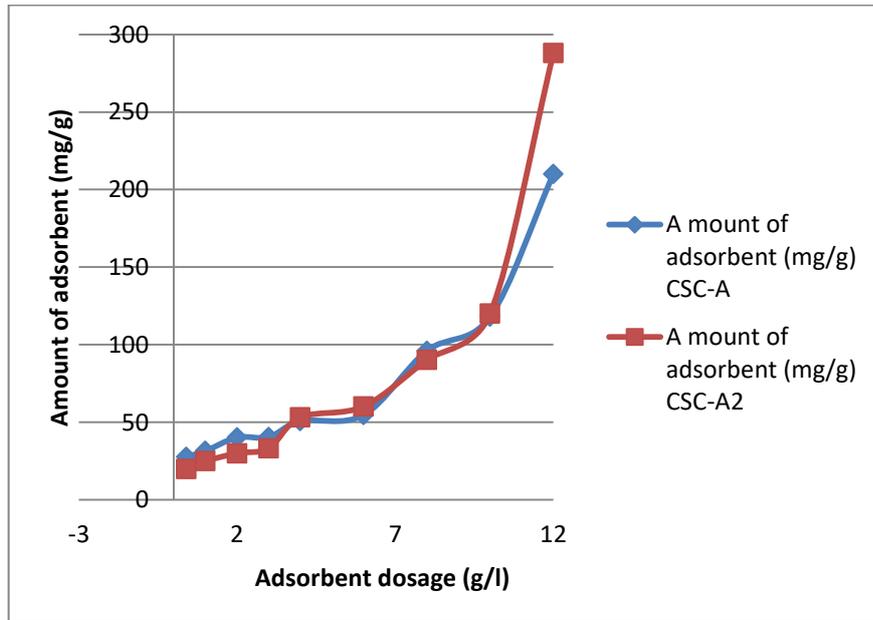


Fig. 3(a) : Coconut shell carbon removal and adsorbent concentration.

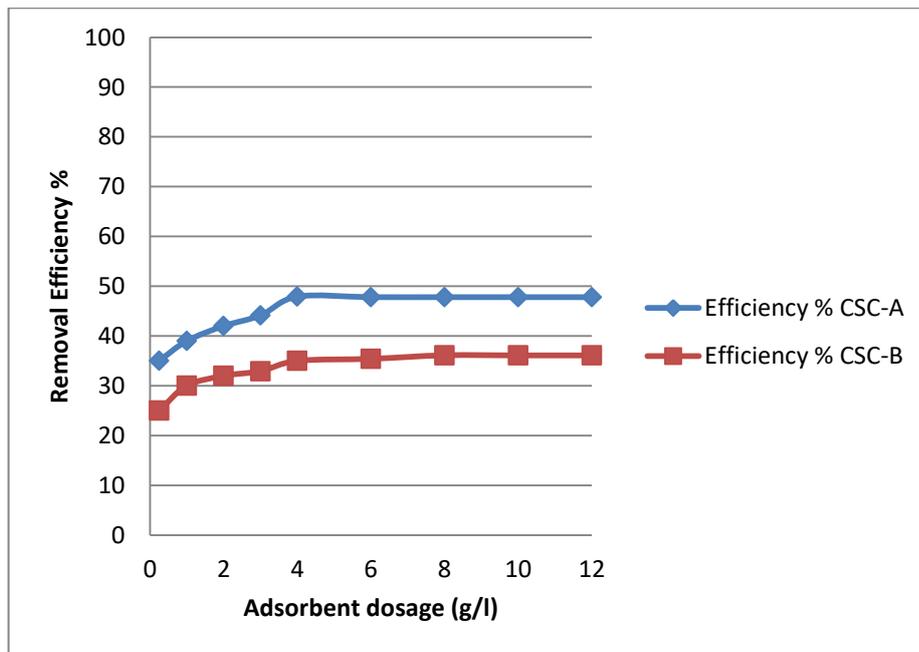


Fig. 3(b) : Coconut shell carbon removal efficiency and adsorbent concentration.

3.3. The impact of Agitation Time and Pb(II) Removal

Figure 4 shows agitation time affects Pb(II) removal. CSC's removal efficiency and adsorption capacity both dramatically improve with extended agitation times. The vast amount of coconut shell carbons that are exposed may have been responsible for the initial high rate of adsorption. When the agitation time is increased, the exposed surface area quickly decreases until adsorption equilibrium is attained [21,23]. The stability of the adsorption equilibrium is significantly affected by the adsorbent's S_{BET} and V_T . As increasing

the surface area of CSC results in more binding sites, this may be used to justify the relatively long adsorption period of 120 minutes [22].

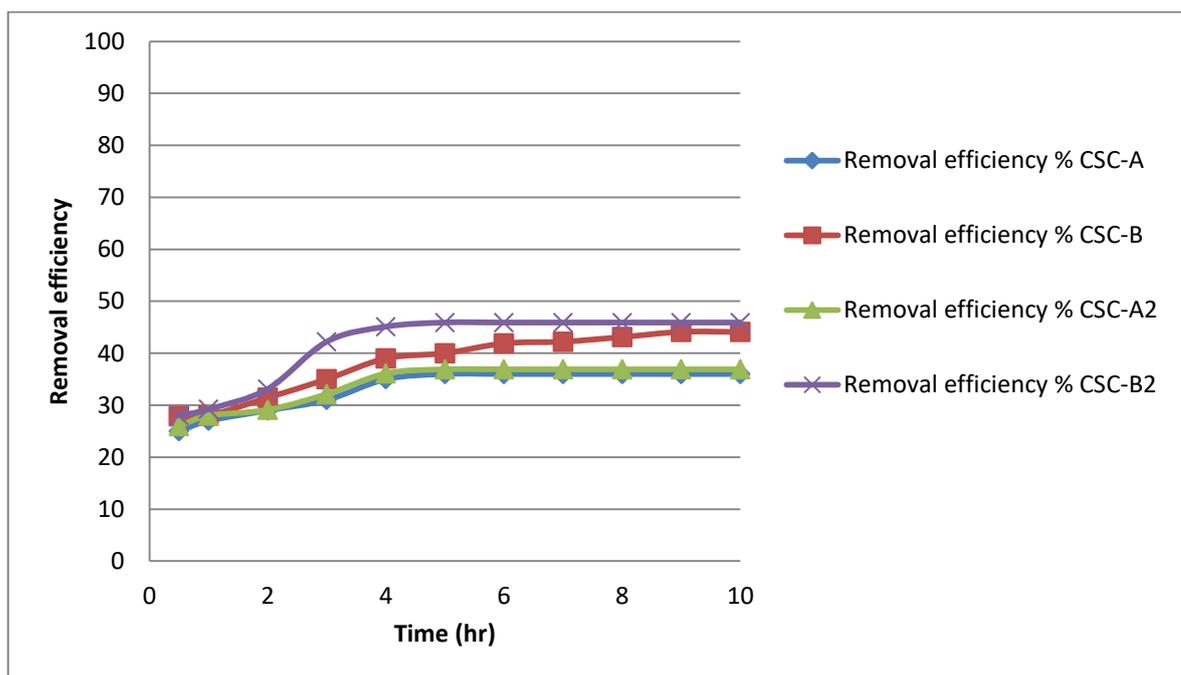


Figure 4: Impact of adsorption duration on the number of carbons in coconut shells that are adsorbed and how well they are removed.

3.4 Initial ion concentration affects Pb(II) removal

In Figure 5, starting ion concentration affects Pb(II) sorption and elimination. When the starting ion concentration rises from 14.57 mg/g to 77.34 and 108.7 mg/g, CSC-A and CSC-removal B's efficiency reduces from 53.3% and 67.5% to 26.4% and 36.7%. Because Pb(II) interactions with adsorbate molecules are facilitated by the presence of adsorbates at lower concentrations. Unfortunately, the adsorption effectiveness of coconut shells decreases as concentrations rise because the carbon atoms in the adsorbate molecules become saturated [24, 25].

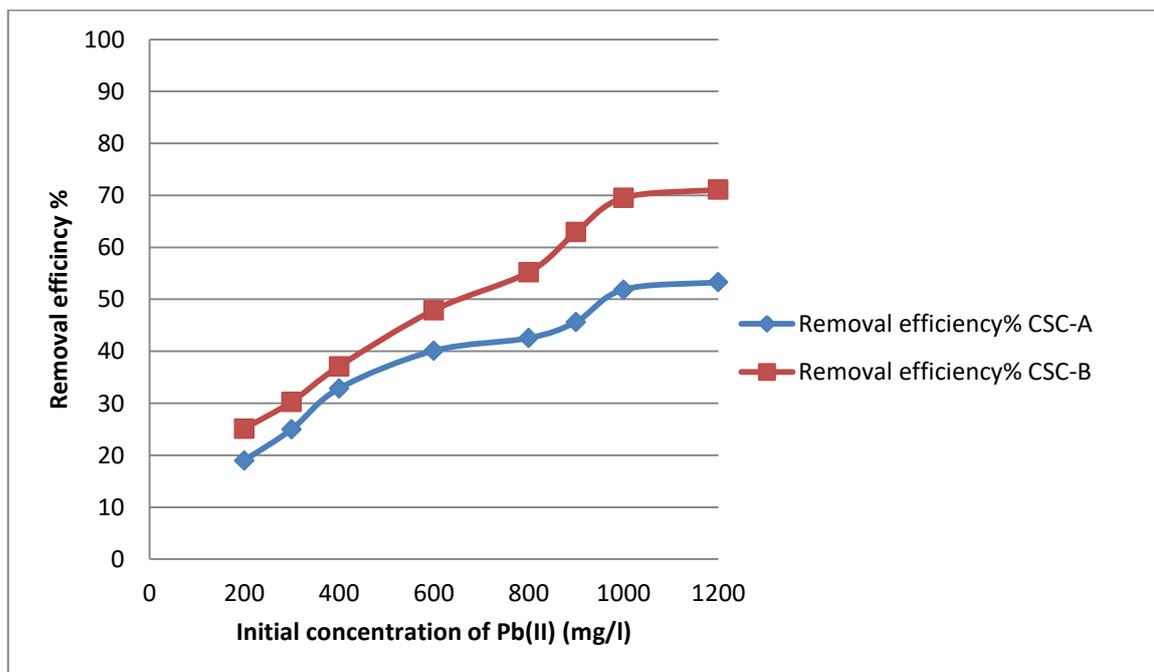


Fig. 5. The quantity and efficiency with which coconut shell carbons are able to remove ions depends on the initial concentration of Pb(II)

4. Adsorption Isotherm

Pb(II) removal adsorption spectra were analyzed using 100 mg/L to 1200 mg/L starting concentrations and a 4 g/L adsorption dosage. The mechanism of Pb(II) sorption on CSC-A and CSC-B was examined using six Langmuir and Freundlich adsorption isotherms. Table 1 lists the six adsorption isotherm features.

Table 1. Adsorption isotherm parameters for Pb²⁺ on carbons isolated from coconut shells.

Parameters	CSC-A	CSC-B
Langmuir isotherm		
q_{max} mg/g	0.0021	151.54
b mg/l	0.0021	0.0027
R1	0.2818	0.2402
R2	0.9288	0.9461
Freundlich isotherm		
n	1.6785	1.6754
K_f	1.3422	2.0188
R²	0.9907	0.9974

A first look at the relevant data suggests that the Freundlich model is a good match for the experimental data because of the high coefficient of correlation (R²), the multilayer sorption onto the coconut shell carbons and the dispersed nature of the active sites [26, 27]. CSC-B has a greater K_f (2.0189) than CSC-A, which is determined from Freundlich isotherms, showing that it has a stronger affinity for Pb II despite having a higher S-BET

and V_T . Pb(II) sorption on coconut shell carbons CSC-A and CSC-B have calculated Langmuir isotherms with Rl values between 0 and 1. The fact that CSC-B has a greater maximum adsorption capacity (q_{max}) than CSC-A (112.39 mg/g) (II) is additional evidence of its powerful potential for adsorbing Pb.

5. Adsorption Isotherm

Adsorption kinetics may be used to investigate the process by which Pb(II) is adsorbed on carbons isolated from coconut shells. In this research, Table 3 displays the several models used to evaluate the reliability of the experimental results: pseudo-first-order, pseudo-second-order, Spahn and Schlünder, and intra-particle diffusion models. [17,32].

Parameter	CSC-A	CSC-B
Pseudo-first-order kinetic model		
K_1	0.7836	1.7762
R^2	0.9342	0.9579
Pseudo-second-order kinetic model		
K_1	0.0392	0.336
R^2	0.9949	0.9962
Intra-particle diffusion model		
Stage 1		
K_1	0.1220	0.2828
R^2		0.9902
Stage2		
K_1	20.5392	45.7459
R^2	0.9842	0.9979
Stage3		
K_1	11.8942	32.3500
R^2	0.9947	0.9571

6. Conclusions

The carbons produced by reacting coconut shells with NaOH are very helpful in removing lead ions from wastewater, Due to their huge specific surface area, The initial ion concentration, adsorbent concentration, and agitation time affect removal efficiency and adsorption capacity were studied to get the optimal values for removing of heavy metals ions from wastewater. Using Freundlich and Halsey isotherms, it is feasible to show the data on the carbon adsorption from coconut shells. Pseudo-second-order kinetics and internal and exterior particle diffusion are used in Adsorption Kinetics.

References

1. Bahadir, T.; Bakan, G.; Altas, L.; Buyukgungor, H. The investigation of lead removal by biosorption: An application at storage battery industry wastewaters. *Enzyme Microb. Technol.* 2007, 41, 98–102.
2. Wang, S.; Gong, W.; Liu, X.; Yao, Y.; Gao, B.; Yue, Q. Removal of lead(II) from aqueous solution by adsorption onto manganese oxide-coated carbon nanotubes. *Sep. Purif. Technol.* 2007, 58, 17–23.
3. Gupta, V.K.; Agarwal, S.; Saleh, T.A. Synthesis and characterization of alumina-coated carbon nanotubes and their application for lead removal. *J. Hazard. Mater.* 2011, 185, 17–23.
4. Li, Y.; Wang, S.; Wei, J.; Zhang, X.; Xu, C.; Luan, Z.; Wu, D.; Wei, B. Lead adsorption on carbon nanotubes. *Chem. Phys. Lett.* 2002, 357, 263–266.
5. Sekar, M.; Sakthi, V.; Rengaraj, S. Kinetics and equilibrium adsorption study of lead(II) onto activated carbon prepared from coconut shell. *J. Colloid Interf. Sci.* 2004, 279, 307–313.
6. O'Connell, D.W.; Birkinshaw, C.; O'Dwyer, T.F. Heavy metal adsorbents prepared from the modification of cellulose: A review. *Bioresour. Technol.* 2008, 99, 6709–6724.
7. Acharya, J.; Sahu, J.N.; Mohanty, C.R.; Meikap, B.C. Removal of lead(II) from wastewater by activated carbon developed from Tamarind wood by zinc chloride activation. *Chem. Eng. J.* 2009, 149, 249–262.
8. Ricordel, S.; Taha, S.; Cisse, I.; Dorange, G. Heavy metals removal by adsorption onto peanut husks carbon: Characterization, kinetic study and modeling. *Sep. Purif. Technol.* 2001, 24, 389–401.
9. Saeed, A.; Iqbal, M.; Akhtar, M.W. Removal and recovery of lead(II) from single and multimetal (Cd, Cu, Ni, Zn) solutions by crop milling waste (black gram husk). *J. Hazard. Mater.* 2005, 117, 65–73.
10. Doyurum, S.; Celik, A. Pb(II) and Cd(II) removal from aqueous solutions by olive cake. *J. Hazard. Mater.* 2006, 138, 22–28.
11. Goel, J.; Kadirvelu, K.; Rajagopal, C.; Garg, V.K. Removal of lead(II) by adsorption using treated granular activated carbon: Batch and column studies. *J. Hazard. Mater.* 2005, 125, 211–220.
12. Cazetta, A.L.; Vargas, A.M.M.; Nogami, E.M.; Kunita, M.H.; Guilherme, M.R.; Martins, A.C.; Silva, T.L.; Moraes, J.C.G.; Almeida, V.C. NaOH-activated carbon of high surface area produced from coconut shell: Kinetics and equilibrium studies from the methylene blue adsorption. *Chem. Eng. J.* 2011, 174, 117–125.
13. Rao, M.M.; Rao, G.P.C.; Seshaiyah, K.; Choudary, N.V.; Wang, M.C. Activated carbon from Ceiba pentandra hulls, an agricultural waste, as an adsorbent in the removal of lead and zinc from aqueous solutions. *Waste Manag.* 2008, 28, 849–858.

14. Li, W.; Yang, K.; Peng, J.; Zhang, L.; Guo, S.; Xia, H. Effects of carbonization temperatures on characteristics of porosity in coconut shell chars and activated carbons derived from carbonized coconut shell chars. *Ind. Crop. Prod.* 2008, 28, 190–198.
15. Bansode, R.R.; Losso, J.N.; Marshall, W.E.; Rao, R.M.; Portier, R.J. Adsorption of metal ions by pecan shell-based granular activated carbons. *Bioresour. Technol.* 2003, 89, 115–119.
16. Jankowska, H.; Swaiatkowski, A.; Choma, J. *Activated Carbon*; Ellis Horwood: New York, NY, USA, 1991.
17. Tofighy, M.A.; Mohammadi, T. Adsorption of divalent heavy metal ions from water using carbon nanotube sheets. *J. Hazard. Mater.* 2011, 185, 140–147.
18. González, J.F.; Román, S.; Encinar, J.M.; Martínez, G. Pyrolysis of various biomass residues and char utilization for the production of activated carbons. *J. Anal. Appl. Pyrol.* 2009, 85, 134–141.
19. Babel, S.; Kurniawan, T.A. Cr(VI) removal from synthetic wastewater using coconut shell charcoal and commercial activated carbon modified with oxidizing agents and/or chitosan. *Chemosphere* 2004, 54, 951–967.
20. Nomanbhay, S.M.; Palanisamy, K. Removal of heavy metal from industrial wastewater using chitosan coated oil palm shell charcoal. *Electron. J. Biotechnol.* 2005, 8, 43–53.
21. Li, Y.; Du, Q.; Wang, X.; Zhang, P.; Wang, D.; Wang, Z.; Xia, Y. Removal of lead from aqueous solution by activated carbon prepared from *Enteromorpha prolifera* by zinc chloride activation. *J. Hazard. Mater.* 2010, 183, 583–589.
22. Amuda, O.S.; Giwa, A.A.; Bello, I.A. Removal of heavy metal from industrial wastewater using modified activated coconut shell carbon. *Biochem. Eng. J.* 2007, 36, 174–181.
23. Aroua, M.K.; Leong, S.P.P.; Teo, L.Y.; Yin, C.Y.; Daud, W.M.A.W. Real-time determination of kinetics of adsorption of lead(II) onto palm shell-based activated carbon using ion selective electrode. *Bioresour. Technol.* 2008, 99, 5786–5792.
24. Mohamed, A.S.; Ghalia, A.Z.; Samia, A.K. Simultaneous removal of copper(II), lead(II), zinc(II) and cadmium(II) from aqueous solutions by multi-walled carbon nanotubes. *C. R. Chim.* 2012, 15, 398–408.
25. Imamoglu, M.; Tekir, O. Removal of copper(II) and lead(II) ions from aqueous solutions by adsorption on activated carbon from a new precursor hazelnut husks. *Desalination* 2008, 228, 108–113.
26. Gong, J.; Liu, T.; Wang, X.; Hu, X.; Zhang, L. Efficient removal of heavy metal ions from aqueous systems with the assembly of anisotropic layered double hydroxide nanocrystals@carbon nanosphere. *Environ. Sci. Technol.* 2011, 45, 6181–6187.
27. Liu, J.; Wang, X. Novel silica-based hybrid adsorbents: Lead(II) adsorption isotherms. *Sci. World J.* 2013, 2013, Article 897159.
28. Shahmohammadi-Kalalagh, S.; Babazadeh, H.; Nazemi, A.H.; Manshouri, M. Isotherm and kinetic studies on adsorption of Pb, Zn and Cu by kaolinite. *Caspian J. Environ. Sci.* 2011, 9, 243–255.

29. Momčilović, M.; Purenović, M.; Bojić, A.; Zarubica, A.; Randelović, M. Removal of lead(II) ions from aqueous solutions by adsorption onto pine cone activated carbon. *Desalination* 2011, 276, 53–59.
30. Issabayeva, G.; Aroua, M.K.; Sulaiman, N.M.N.S. Removal of lead from aqueous solutions on palm shell activated carbon. *Bioresour. Technol.* 2006, 97, 2350–2355.
31. Kobya, M.; Demirbas, E.; Senturk, E.; Ince, M. Adsorption of heavy metal ions from aqueous solutions by activated carbon prepared from apricot stone. *Bioresour. Technol.* 2005, 96, 1518–1521.
32. Figaro, S.; Avril, J.P.; Brouers, F.; Ouensanga, A.; Gaspard, S. Adsorption studies of molasse's wastewaters on activated carbon: Modelling with a new fractal kinetic equation and evaluation of kinetic models. *J. Hazard. Mater.* 2009, 161, 649–656.