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Fexofenadine Adsorption by Activated Charcoal Impregnated with Hydrogen Peroxide

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Abstract

The adsorption of fexofenadine drug by activated charcoal powder impregnated with hydrogen peroxide (IAC) to improve its surface properties was investigated. The investigation also aimed to assess the effect of the repeated dose in increasing the amount of the drug adsorbed. The powder activated charcoal was impregnated with H₂O₂ 3%. The effects of pH of the solution, concentration of the drug and time of the reaction parameters were investigated by using UV-Vis spectroscopy. The IAC was brought in contact with the drug solution in different pH (2, 4, 7 and 9), drug concentrations (30, 60, 90 and 120 µg ml⁻¹) and time (15, 30, 45 and 60 minutes). After each experiment, a repeated dose of IAC was introduced into the solution and the adsorption process was repeated. The results showed that the amounts of the drug adsorbed were decreased with increasing the pH and increased with increasing the concentration of solution and time of contact. The adsorption capacity was enhanced to about 70% after the addition of the repeated dose. The study showed a spectrum displacement toward the blue region (blue shift) for the drug supernatant in all experiment parameters, which was almost doubled when a repeated dose was added.

Keywords: Fexofenadine, Activated charcoal, Drug, Adsorption, Repeated dose.

إمتزاز الفيكسوفينادين بواسطة فحم منشط معبأ ببيروكسيد الهيدروجين

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الخلاصة

تمت دراسة إمتزاز عقار الفيكسوفينادين بواسطة فحم منشط معبأ ببيروكسيد الهيدروجين لتحسين صفاته السطحية. تهدف الدراسة أيضا إلى تقييم تأثير الجرعة المكررة في زيادة الكمية الممتزة من الدواء. تمت دراسة تأثير الأس الهيدروجيني, التركيز وزمن التفاعل باستخدام مطيافية المرئية/فوق البنفسجية. تمت تعبئة الفحم المنشط ببيروكسيد الهيدروجين 3% ثم مفاعله مع العقار عند أس هيدروجيني مقداره 2, 4, 7 و 9 وتركيز العقار 30, 60, 90 و 120 ميكروغرام مل⁻¹ وزمن تفاعل 15, 30, 60 و 90 دقيقة. بعد كل تجربة تم إضافة جرعة مكررة وإعادة العملية. بينت النتائج ان كمية العقار الممتزة قلت بزيادة الأس الهيدروجيني وزادت بزيادة التركيز وزمن التفاعل. تحسنت قدرة الإمتزاز بمقدار 70% بعد إضافة الجرعة الثانية من الفحم المنشط. بينت الدراسة بان هنالك إزاحة للطيف فوق البنفسجي لمحلول العقار نحو المنطقة الزرقاء بعد تفاعله مع الفحم, تضاعفت بعد إضافة الجرعة المكررة.

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1. Introduction

Activated charcoal is the most effective adsorbent species used in the medical field. It is a carbon porous material that interacts with gases during the carbonization process to increase its porosity, which in turn increases its surface area [1]. The process of activated charcoal preparation consists of two steps; activation and carbonization. The product has high porosity material with a surface area of 300 m²/g and possibly more than 5000 m²/g. The extent of the surface area of activated charcoal depends on the preparation technique employed in the production [2]. The granular form of activated charcoal is used in gas masks [3] and the powdered form is used for adsorption of various types of chemicals and drugs [4]. The adsorption of diclofenac on activated charcoal was studied in a batch process and fixed-bed column. It was found that the Freundlich equation is quite suitable to describe the behavior of the isotherms at 298, 308 and 318 K [5]. A study of adsorption of sodium diclofenac on activated charcoal produced from potato peel waste and commercial activated charcoal showed that the kinetic data of both activated charcoals was best fitted by the pseudo-second-order model [6]. The diclofenac sodium was also adsorbed on *Cyclamen persicum* tubers activated charcoal. It was found that the adsorption process increases with increasing the concentration of the compound, and the optimum pH of adsorption was between 2 and 6. The process was well described by the Freundlich model [7]. The competitive adsorption of amoxicillin and ibuprofen on activated charcoal of different properties was also studied. It was shown that the capacities of the equilibrium adsorption depend on the porous features of the activated charcoal's pH, density of surface and ionization of the drugs [8]. The adsorption of cephalexin, amoxicillin, tetracycline and penicillin G from aqueous solutions on activated charcoal produced from vine wood was also investigated. The study showed that the activated charcoal has a good ability to remove the drugs [9]. The effects of different parameters such as pH and temperature on the adsorption of cephalexin on activated charcoal obtained from walnut shell was also studied [10]. Kinetic and equilibrium studies of the removal of tetracycline by activated charcoal showed that the best fitted model of isotherm to experimental data is Temkin and the best fitted kinetic model is Elovich [11]. The maximum adsorption of tetracycline from drinking water on activated charcoal activated by NaOH was found to be 897.6, 961.5 and 1121.5 mg/g at the temperatures of 303, 313 and 323 K, respectively. The process was studied at different parameters such as pH, concentration, time, temperature and ionic strength, and found to be fit with Freundlich and pseudo-second-order models [12]. The adsorption of some non-steroidal anti-inflammatory drugs such as naproxen, diclofenac and ibuprofen on activated charcoal was investigated and the intensity of the interactions between the three drugs and the activated charcoal was determined [13]. Equilibrium and dynamic investigations concerning the adsorption of diclofenac and caffeine on granular activated charcoal showed lower adsorption capacities in the competitive case compared with the single adsorption case [14]. The process of adsorption of carbamazepine, sildenafil citrate and methylparaben on granular activated charcoal showed that the nonlinear model was capable of describing the behavior of adsorption kinetic [15]. The removal of acyclovir from aqueous solution by activated charcoal was studied and it was found that the Freundlich model is the best to describe the process [16]. The removal of tetracycline from the aqueous solution on activated charcoal was found to increase with the increase in ion strength, contact time, drug concentration and solution temperature [17]. The adsorption capacity of the porous surface of activated charcoal can be enhanced via oxidation by different oxidizing agents [18, 19]. Oxidation of activated charcoal with hydrogen peroxide, ammonium persulphate and nitric acid was found to be capable of enhancing the adsorption process [20, 21]. H₂O₂ is decomposed after reacting with activated charcoal [22]. One of the important concepts related to working on activated charcoal is the use of a repeated dose which has an important role in increasing the amount of the species adsorbed. Repeated doses of activated charcoal can increase the elimination and clearance of a wide range of drugs from bodies of people who have been poisoned by medications [23]. This approach was found to be efficient in removing digitoxin and verapamil [24], phenytoin [25] and theophylline [26] from young infants who were poisoned by these drugs. Fexofenadine is a second generation antihistamine which exists as a white crystalline solid that is slightly soluble in water. It is usually used for the relief from physical symptoms associated with seasonal allergic rhinitis. It is also used for the treatment of chronic urticaria. The chemical formula is C₃₂H₃₉NO₄, and the chemical name is 2-(4-(1-hydroxy-4-[4-(hydroxydiphenylmethyl) piperidino] butyl phenyl)-2-methylpropanoic acid [27, 28].

The objective of the current research is to investigate the adsorption process of fexofenadine on activated charcoal in the case of patients with overdose ingestion, as well as to estimate the effectiveness of the repeated dose of activated charcoal and its impact on the process of detoxification. The activated charcoal was modified with hydrogen peroxide.

2. Experimental part

2.1 Materials

All chemicals used in the current research, including activated charcoal, were of analytical grade and obtained from Sigma-Aldrich. The fexofenadine drug (120 mg tablet) was purchased from the local market and produced by Micro Labs Limited Company.

2.2 Instrumentation and UV Spectroscopy conditions

The UV-Vis electronic spectra were recorded on a PG instrument T80 UV/Vis double beam spectrophotometer. The pH of the solution was monitored using a Philips (PW-9409) digital pH meter. The wavelength of fexofenadine at which maximum absorbance occurs (λ_{max}) was recorded for the aqueous solution of the drug and found to be 220 nm.

2.3 Adsorption Assays

The activated charcoal was washed several times with distilled water before use and then dried to constant weight at 105°C for over 4 hours. The stock solution (120 $\mu\text{g ml}^{-1}$) of the fexofenadine drug was obtained by dissolving a 120 mg tablet in 60 ml ethanol in a 250 ml conical flask. The solution was then left on a magnetic stirrer for 15 minutes in order to dissolve the sample completely. Ethanol solution (60 ml) was then transferred to a volumetric flask and the volume was adjusted up to 1 L with distilled water. The solution was then filtered through Whatman filter paper. The impregnation of activated charcoal was carried out by immersing the powder in 3% hydrogen peroxide solution under a neutral condition for 4 hours with stirring. The powder was then separated by filtration, washed several times with distilled water, and dried in open air for one hour and then in the furnace at 105°C for 4 hours in order to remove the content of the impregnation solvent and water. The adsorption experiments were carried out to study the effects of pH, concentration and time, along with the impacts of the repeated dose, on the process. In a batch experiment, 50 ml of the 120 $\mu\text{g ml}^{-1}$ fexofenadine solution was placed in a flask and then 1 gm of the IAC was added to the solution at pH values of 2, 4, 7 and 9. The pH was adjusted using 0.1 N solution of HCl and NaOH. The mixtures were left on a magnetic stirrer for 60 minutes, then the absorbance of the solution was measured at $\lambda=220$ for residual drug concentration. A repeated dose of another 1 gm IAC was added to the mixture and the stirring continued for another 60 minutes, after which the residual drug concentration was measured at the same wavelength. For the concentration study, the experiment was repeated for 60 minutes using fexofenadine concentrations of 30, 60, 90 and 120 $\mu\text{g ml}^{-1}$. For the time study, the experiment was repeated at different periods of time of 15, 30, 45, and 60 minutes using a drug concentration of 120 $\mu\text{g ml}^{-1}$. To calculate the amount of fexofenadine adsorbed, the following equation was used:

$$q_e = \frac{(C_i - C_e)V}{m}$$

where q_e is the maximum quantity of the drug in $\mu\text{g gm}^{-1}$ adsorbed on the IAC, C_i is the initial concentration ($\mu\text{g ml}^{-1}$) of the drug solution, C_e is the concentration of the drug ($\mu\text{g ml}^{-1}$) in the supernatant at the equilibrium stage, V is the volume of the drug solution in ml, and m is the mass of adsorbent employed in grams. The calibration curve was performed by measuring the solutions absorbance for each experiment, then plotting the absorbance versus pH, concentration and time.

3. Results and Discussion

The drug has an absorption peak at 220 nm in both water and ethanol, as reported [27,29]. The UV absorption spectrum of the fexofenadine is shown in Figure-1 which shows that the drug has a maximum absorption peak at 220 nm.

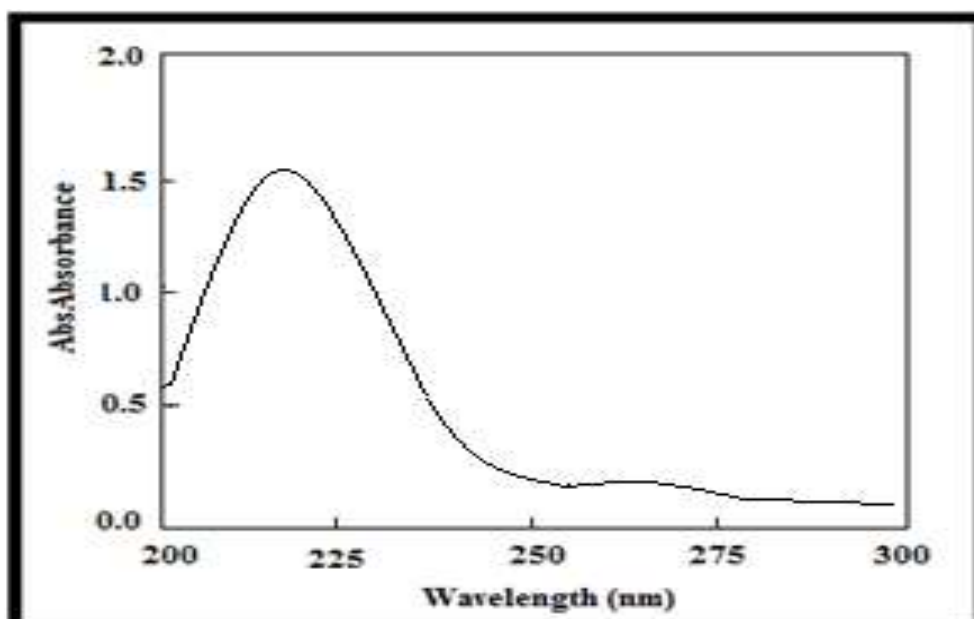


Figure 1- The UV spectrum of fexofenadine in a mixture of water and ethanol.

The parameters for the pH study are listed in Table-1. The second column indicates the amount of drug that was adsorbed after the addition of the first dose. The third column indicates the amount of drug that was adsorbed by the repeated dose of IAC in the second stage. The numbers in last column refer to the total amounts of the drug adsorbed. The parameters for the experiment of the effect of concentration are listed in Table-2, while Table-3 contains the parameters for the effect of time experiment. It is clear from Table-1 that the amount of fexofenadine adsorbed on 1 gm IAC increases with decreasing the pH. The highest value was found at pH 2, which appeared to be compatible since the acidity of the gastric fluid was between 1.5 and 3.5. Figure-2 summarizes the relationship between the pH and the amount of the drug adsorbed. From the inspection of the parameters in Table-2 which includes the amount of fexofenadine adsorbed at different concentrations on IAC, we note that the amounts of the drug adsorbed are increased with increasing the concentration of the drug solution.

Table 1- The results of pH effect on adsorption.

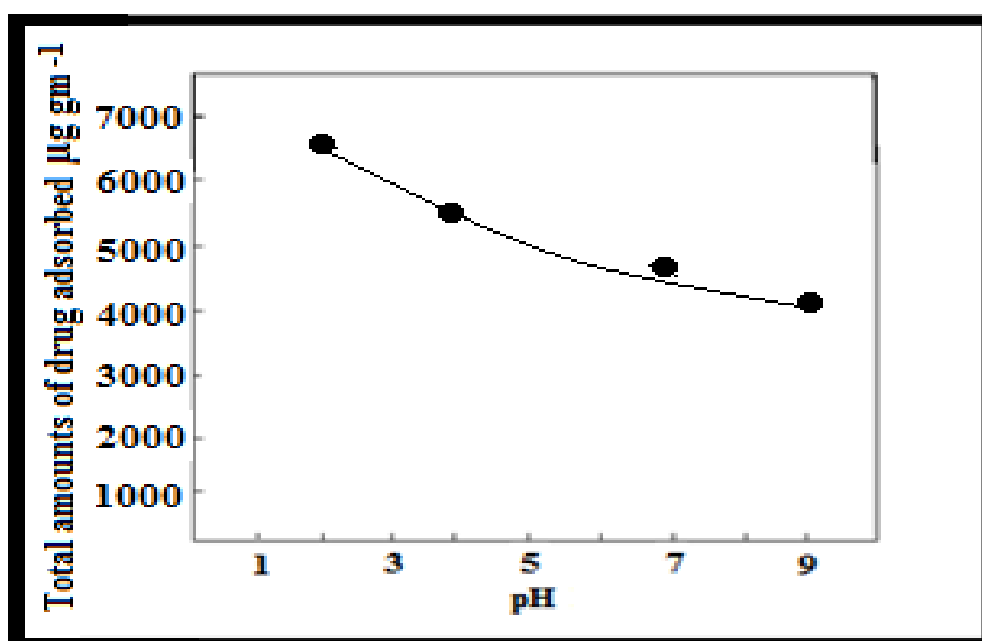
pH	Fexofenadine ($\mu\text{g gm}^{-1}$) adsorbed on IAC	Fexofenadine ($\mu\text{g gm}^{-1}$) adsorbed on repeated dose IAC	Total ($\mu\text{g gm}^{-1}$)
2	3800	2900	6700
4	3500	2400	5900
7	3100	1800	4900
9	2400	1600	4000

Table 2- The results of concentration effect on adsorption..

Concen. ($\mu\text{g ml}^{-1}$)	Fexofenadine ($\mu\text{g gm}^{-1}$) adsorbed on IAC	Fexofenadine ($\mu\text{g gm}^{-1}$) adsorbed on repeated dose IAC	Total ($\mu\text{g gm}^{-1}$)
30	1100	700	1800
60	2100	1400	3500
90	2400	2100	4500
120	3100	2100	5200

Table 3- The results of time effect on adsorption.

Time (min.)	Fexofenadine ($\mu\text{g gm}^{-1}$) adsorbed on IAC	Fexofenadine ($\mu\text{g gm}^{-1}$) adsorbed on repeated dose IAC	Total ($\mu\text{g gm}^{-1}$)
15	1800	1600	3400
30	2200	2000	4300
45	3000	2100	5100
60	3300	2200	5500

**Figure 2-** The effect of increasing the pH on the amount of fexofenadine adsorbed on IAC .

The third parameter was the adsorption time. The study showed similar adsorption behavior to that observed for the concentration parameter. As the time of the adsorption was increased, the amount of the drug adsorbed increased. Figures-(3 and 4) illustrate the relationship between the adsorption of the drug with concentration and time, respectively.

The average percentage increase in the amount of the drug adsorbed after the addition of the repeated dose IAC (Table-4) shows that the repeated dose has a high impact on the adsorption process. The percentage of the drug adsorbed was increased to about 70% after the addition of the repeated dose of the activated charcoal, which was very evident in all the experiments performed.

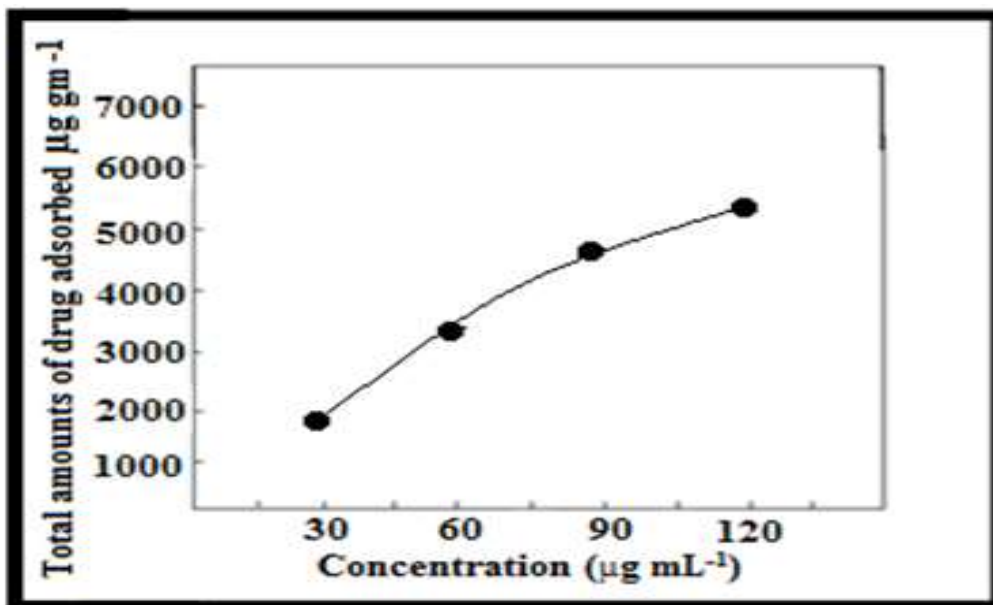


Figure 3- The effect of increasing the drug concentration on the total amount of the drug adsorbed.

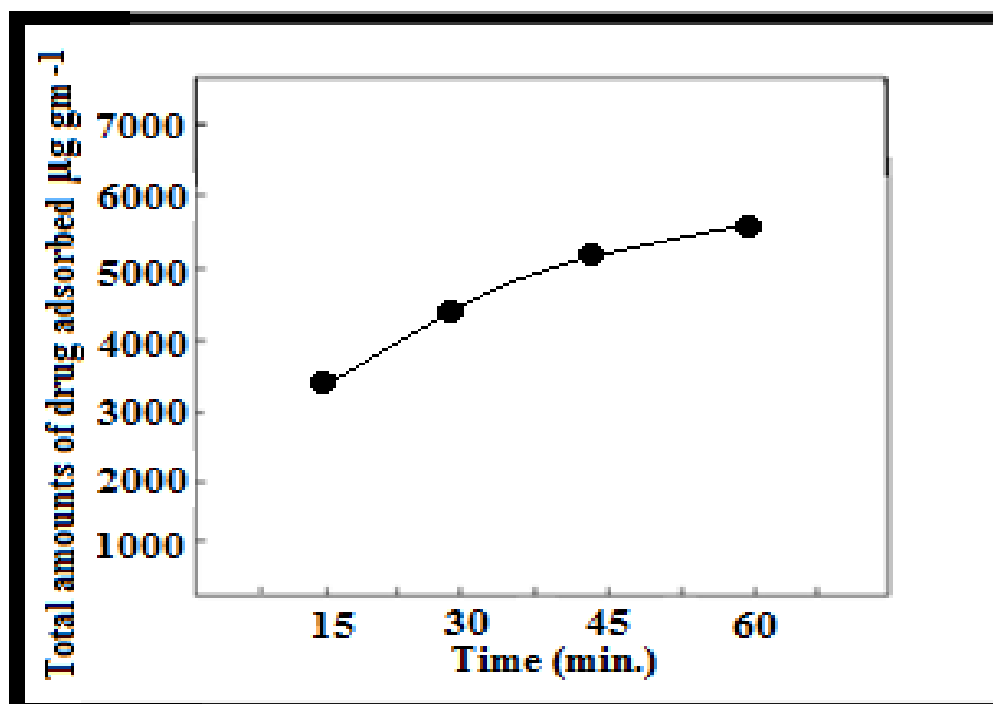


Figure 4- The effect of increasing the time on the total amount of the drug adsorbed.

Table 4- The effect of the repeated dose of IAC on fexofenadine adsorption (%).

% Adsorption increase in pH study	% Adsorption increase in concentration study	% Adsorption increase in time study
67.5	72	77.5

As we mentioned earlier, the spectra were recorded at 220 nm although a blue shift of about 10 nm was observed in the position of the peak of the supernatant. The reason for the displacement of the peak position is possibly due to a change in the polarity of the drug molecule after reacting with the IAC surface. It was reported that some organic compounds' absorption spectra were blue shifted when they were in contact with adsorbents such as montmorillonite clay [30]. It is of interest to know that it

was observed that the longer the reaction time, the greater the blue shift of the peaks, and that the lower the concentration the greater the blue shift. This suggests that the longer the drug is in contact with the IAC surface, the greater will be the effect of the surface on the drug molecules. Also, the lower concentration of the drug means that fewer molecules are in contact with the surface of the IAC, where the ratio of the number of molecules to the surface area of IAC here is lower, which generates a greater impact of the IAC surface on the drug molecules. When the repeated dose is introduced into the solutions, an additional increase in the blue shift was obvious in all of the experimental parameters.

4. Conclusions

The adsorption of fexofenadine drug on the activated charcoal powder impregnated with hydrogen peroxide (IAC) was investigated. The effects of pH, concentration, and time were assessed along with the effect of the repeated dose on the adsorption process. It was found that the amount of the drug adsorbed was decreased with increasing the pH. The maximum amount of the drug adsorbed was achieved at pH 2. The quantities of the drug adsorbed were increased with increasing the concentration and time of contact. It was also found that the amount of fexofenadine adsorbed was increased by about 70% when the repeated dose of IAC was used. The λ_{\max} absorption peak of the drug supernatant was blue shifted by about 10 nm due to the interaction with the IAC.

References

1. Abioye, A. M. and Ani, F. N. **2017**. Advancement in the production of activated carbon from biomass using microwave heating. *Jurnal Teknologi*, **79**(3): 79-88.
2. Hassen, J. H. **2017**. Effect of KOH ratio on the formation of activated carbon from pressed wood residues. *International Journal of Pharmaceutical Sciences and Research*, **8**(11): 4875-4880.
3. Marsh, H. and Rodriguez-Reinoso, F. **2006**. *Activated carbon*. 1st ed. Elsevier Science.
4. Hassen, J. H., Farhan, Y. M. and Ayfan, A. H. **2018**. Comparative study of levocetirizine elimination by pristine and potassium permanganate modified activated charcoal. *International Journal of Pharmaceutical Sciences and Research*, **9**(12): 5155-5160.
5. Espina de Franco, M. A., Bonfante de Carvalho, C., Bonetto, M. M., Soares, R. and Féris, L. A. **2018**. Diclofenac removal from water by adsorption using activated carbon in batch mode and fixed-bed column: isotherms, thermodynamic study and breakthrough curves modeling. *Journal of Cleaner Production*, **181**: 145-154.
6. Bernardo, M., Rodrigues, S., Lapa, N., Matos, I., Lemos, F., Batista, M. K. S., Carvalho, A. P. and Fonseca, I. **2016**. High efficacy on diclofenac removal by activated carbon produced from potato peel waste. *International Journal of Environmental Science and Technology*, **13**(8): 1989-2000.
7. Jodeh, S., Abdelwahab, F., Jaradat, N., Warad, I. and Jodeh, W. **2016**. Adsorption of diclofenac from aqueous solution using *Cyclamen persicum* tubers based activated carbon (CTAC). *Journal of the Association of Arab Universities for Basic and Applied Sciences*, **20**: 32-38.
8. Mansouri, H., Carmona, R. J., Gomis-Berenguer, A., Souissi-Najar, S., Ouederni, A. and Ania, C. O. **2015**. Competitive adsorption of ibuprofen and amoxicillin mixtures from aqueous solution on activated carbons. *Journal of Colloid Science*, **449**: 252-260.
9. Pouretedal, H. R. and Sadegh, N. **2014**. Effective removal of Amoxicillin, Cephalexin, Tetracycline and Penicillin G from aqueous solutions using activated carbon nanoparticles prepared from vine wood. *Journal of Water Process Engineering*, **1**: 64-73.
10. Nazari, G., Abolghasemi, H., Esmaili, M. and Pouya, E. S. **2016**. Aqueous phase adsorption of cephalexin by walnut shell-based activated carbon: A fixed-bed column study. *Applied Surface Science*, **375**: 144-153.
11. Martins, A. C., Pezoti, O., Cazetta, A. L., Bedin, K. C., Yamazaki, D. A. S., Bandoch, G. F. G., Asefa, T., Visentainer, J. V. and Almeida, V. C. **2015**. Removal of tetracycline by NaOH activated carbon produced from macadamia nut shells: Kinetic and equilibrium studies. *Chemical Engineering Journal*, **260**: 291-299.
12. Zhang, D., Yin, J., Zhao, J., Zhu, H. and Wang, C. **2015**. Adsorption and removal of tetracycline from water by petroleum coke-derived highly porous activated carbon. *Journal of Environmental Chemical Engineering*, **3**(3): 1504-1512.
13. Jung, C., Boateng, L. K., Flora, J. R. V., Oh, J., Braswell, M. C., Son, A. and Yoon, Y. **2015**. Competitive adsorption of selected non-steroidal anti-inflammatory drugs on activated biochars: Experimental and molecular modeling study. *Chemical Engineering Journal*, **264**: 1-9.

14. Sotelo, J. L., Ovejero, G., Rodriguez, A., Alvarez, S., Galan, J. and Garcia, J. **2014**. Competitive adsorption studies of caffeine and diclofenac aqueous solutions by activated carbon. *Chemical Engineering Journal*, **240**: 443-453.
15. Delgado, N., Capparelli, A. L., Marino, D. J. and Navarro, A. F. **2016**. Adsorption of pharmaceuticals and personal care products on granular activated carbon. *Journal of Surface Engineered Materials and Advanced Technology*, **6**(4): 183-200.
16. Jain, S., Vyas, R. K., Pandit, P. and Dalai, A. K. **2014**. Adsorption of antiviral drug, acyclovir from aqueous solution on powdered activated charcoal: kinetics, equilibrium, and thermodynamic studies. *Desalination and Water Treatment*, **52**(25-27): 4953-4968.
17. Saygili, H. and Guzel, F. **2016**. Effective removal of tetracycline from aqueous solution using activated carbon prepared from tomato (*Lycopersicon esculentum* mill.) industrial processing waste. *Ecotoxicology and Environmental Safety*, **131**: 22-29.
18. Jung, M. J., Jeong, E., Lim, J. W., Lee, S. I., and Lee, Y. S. **2011**. Physico-chemical surface modification of activated carbon by oxyfluorination and its electrochemical characterization. *Colloids and Surfaces A*, **389**(1): 274- 280.
19. Utrilla, J. R., Polo, M. S., Serrano, V. G., Alvarez, P. M., Alvim-Ferraz, M. C. and Dias, J. M. **2011**. Activated carbon modifications to enhance its water treatment applications. An overview. *Journal of Hazardous Materials*, **187**(1): 1-23.
20. Vasu, A. E. **2008**. Surface modification of activated carbon for enhancement of nickel(II) adsorption. *E-Journal of Chemistry*, **5**(4): 814-819.
21. Moreno-Castilla, C., Lopez-Ramon, M. V. and Carrasco-Marin, F. **2000**. Changes in surface chemistry of activated carbons by wet oxidation. *Carbon*, **38**: 1995-2001.
22. Khalil, L. B., Girgis, B. S., Tawfik, T. A. M. **2000**. Decomposition of H₂O₂ on activated carbon obtained from olive stones. *Journal of Chemical Technology and Biotechnology*, **76**: 1132-1140.
23. McLuckie, A., Forbes, A. M. and Ilett, K. F. **1990**. Role of repeated doses of oral activated charcoal in the treatment of acute intoxications. *Anaesthesia and Intensive Care*, **18**(3): 375-384.
24. Hantson, P., Vandenplas, O., Mahieu, P., Wallemacq, P. and Hassoun, A. **1991**. Repeated doses of activated charcoal and cholestyramine for digitoxin overdose: pharmacokinetic data and urinary elimination. *Journal de Toxicologie Clinique et Experimentale*, **11**(7-8): 401-405.
25. Gary, D., Weichbrodt, G. D. and Elliott, D. P. **1987**. Treatment of phenytoin toxicity with repeated doses of activated charcoal. *Annals of Emergency Medicine*, **16**(12): 1387-1389.
26. Shannon, M., Amitai, Y. and Lovejoy, F. H. **1987**. Multiple dose activated charcoal for theophylline poisoning in young infants. *Pediatrics*, **80**(3): 368-370.
27. Safila, N., Qamar, F., Zainab, S., Ghulam, S. and Tanweer, M. A. **2015**. Assay of fexofenadine brands using UV Spectrophotometer. *American Journal of Innovative Research and Applied Sciences*. **1**(1): 10-13.
28. Rele, R. V. **2016**. UV spectrophotometric estimation of fexofenadine hydrochloride by first order derivative and area under curve methods in bulk and pharmaceutical dosage form. *Der Pharmacia Lettre*, **8**(10): 95-101.
29. Breier, A. R., Steppe, M. and Schapoval, E. E. S. **2007**. Validation of UV spectrophotometric method for fexofenadine hydrochloride in pharmaceutical formulations and comparison with HPLC. *Analytical Letters*, **40**(12): 2329-2337.
30. Yamabe, K. and Goto, H. **2018**. Synthesis and surface observation of montmorillonite/polyaniline composites. *Journal of Composites Science*, **2**(1): 1-8.