ADSORPTIVE REMOVAL OF ANTI - EPILEPTIC DRUG - CARBAMAZEPINE BY ACTIVATED CARBON

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Abstract
This work describes the adsorption process of one of the most dominant pharmaceuticals detected in water sources, carbamazepine (CBZ), from aqueous solutions with commercially available activated carbon (AC). Adsorption studies were performed on powdered activated carbon Norit SA2, in ambient temperature, on pH value between 2 – 10, with different masses of adsorbent (6 – 20 mg), time intervals (5 – 60 min). The CBZ adsorption is explained by chemisorption which involves chemical reaction between surface and adsorbate. The results show that commercial activated carbon Norit SA2 can be applied in the process of adsorption for the purpose of removing carbamazepine from aqueous solution.

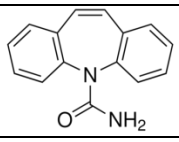
Keywords: adsorption, pharmaceuticals, carbamazepine, activated carbon, pH value.

Introduction

During the last decades the phenomenon of drugs detection and classification as emerging substances in aquatic environment has been recognized as one of the most important environmental issues [1]. Among the chemicals, pharmaceuticals present large and diverse group of compounds designed to prevent, cure and treat diseases and improve health. Only in the European Union (EU) around 3000 different pharmaceutically active compounds (PhACs) are approved for use in human medicine. Furthermore, the increasing consumption of these compounds has resulted in significant concentrations in groundwater, surface water and treated wastewater effluents [2], [3], [4]. Mostly, pharmaceuticals cannot be completely eliminated from living organisms' bodies and they are excreted, causing their constant release in aqueous compartment. The widespread occurrence of pharmaceutical active compounds in surface water could be explained by their presence in domestic and industrial wastewater released into water media without adequate treatment [5]. There are currently no legally regulated maximum permitted concentrations of pharmaceuticals in the environment, despite their unknown impact on the environment and human health [6].
Carbamazepine (CBZ) (5H-Dibenz(b,f)azepine-5-carboxamide) (Table 1) as an neutral antiepileptic drug is among the most frequently reported pharmaceuticals in surface waters observed at a concentration more than 10 times higher than other micropollutants due to its high persistency [7]. Major quantity of research focusing on the removal of pharmaceuticals from wastewaters revealing that the existing conventional available treatment options are not beneficial in the elimination of these compounds [8]. Various treatment technologies have been introduced for removal of micropollutants from effluents such as coagulation - flocculation, chemical oxidation, and adsorption. With a low value of the distribution coefficient (K_d = 1.2 L g $^{-1}$), carbamazepine can't be removed in treatment processes like anaerobic digestion. Therefore, discharge of effluents from urban wastewater treatment plants to environment could lead to occurrence of CBZ in the aquatic environments, and

subsequently in drinking water. Finding solution in the efficient post treatment could be of great importance to reduce the release of carbamazepine into surface waters.

Table 1. The physico chemical properties of CBZ

	Chemical structure	Molecular weight	pKa	$logK_{ow}$
Carbamazepine		236.27	2.3	2.45

Among the various treatment technologies that have been introduced for the purification and wastewater treatment, adsorption is one of the most effective methods of removing various micropollutants. Benefits of adsorption technology are reflected in high efficiency, easy handling, availability and cost-effectiveness of various adsorbents [9]. Activated charcoal, natural clays, modified clays and industrial waste, were used as adsorbents for the removal of wide range of micropollutants from wastewater solution [10], [11], [12]. Among them, natural clays showed good results as adsorbents to remove various metals, organic compounds and color.

However, some adsorbents such as carbon nanotube, graphene oxide, and functionalized materials showed a low potential for large-scale applications for the removal of organic burden [1].

Activated carbon (AC) is one of the well-known adsorbent which has great specific surface area, pore structure and one of the main advantages of using activated carbon to remove pharmaceuticals is that it does not generate toxic or pharmacologically active products [6]. High availability of AC in the market and considerable amount of research that has been published, define AC in a group of materials that can be used in the process of pharmaceuticals removing.

The aim of this study was to comprehensively evaluate the adsorption of carbamazepine onto activated carbon made from peat materials. In order to optimize processes of adsorption, influence of operational parameters was investigated. The operational parameters such as adsorbent dosage, pH value, contact time and initial concentration were changed in different experiments.

Experimental

Chemicals and reagents

Carbamazepine (CBZ, purity ≥99.0%) was purchased from Sigma Aldrich, Germany and used without further purification. Acetonitrile and formic acid (HPLC grade) were also obtained from Sigma Aldrich. The powdered activated carbon (Norit SA2) was obtained from Thermo Fisher Scientific, USA. The stock solution was prepared by dissolving 5 mg of analytical standard in 25 ml of acetonitrile (final concentration of 200 mgL^{-1}) and the working solutions were obtained by diluting the stock solution with distilled water. As aqueous matrix, distilled water was used. For pH adjustment, solution of 0.1% HCl and 1% of NaOH were used. All chemicals used in experiments were of analytical grade.

Adsorption experiments

Adsorption assays were performed in batch mode at room temperature (25°C). In order to analyze influence of pH value, five different pH values were used (2, 5, 7, 9 and 10). The initial concentration of CBZ was 5 mgL^{-1}, prepared in 50mL Erlenmeyer flasks. After pH adjustment, samples were agitated at mechanic shaker at 140 rpm. The contact time between adsorbent and pharmaceutical was 30 minutes. After stirring, all samples were filtered

through filter paper in order to remove activated carbon from solution. After performed experiment, 1 mL of samples were transferred into 2 mL vials.
The influence of mass dosage on adsorption processes was performed in 50 mL aqueous solution of carbamazepine with different masses of adsorbent (6, 8, 10, 12 and 20 mg). Kinetic studies were investigated in different time intervals (5-60 minutes). The initial concentration of carbamazepine was 5 mgL^{-1}.

Analytical procedure
For determination of remaining pharmaceutical residues, HPLC with diode array detector (Agilent 1260 series) was applied. Chromatography separation was performed at reverse stationary phase Eclipse XDB-C18 (150 x 4.6, particle size 5µm) at flow rate of 0.2 ml min^{-1} and injection volume of 10 µL at room temperature. Mobile phases were consisted of: A – 0.1 formic acid and B – acetonitrile. Gradient elution mode was as follows: 20% of B for 3 min, 45% of B at 25 min, for 30% of B at 27 min and in 30-minute initial conditions were applied. The maximum absorbance for observed pharmaceutical is 290 nm.

Results and discussion
Influence of pH value
The pH value represents one of crucial parameters which have influence on adsorption capacity. Changes in the pH affect the ionization degree and the solubility of the solute as well as the surface charge of the adsorbent. Figure 1. shows the effect of pH value on CBZ adsorption.

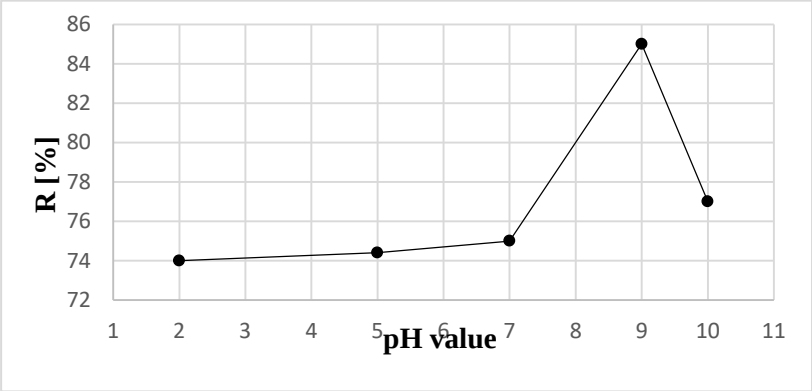


Figure 1. The effect of pH value

Intensity of interactions remains almost constant at acid and neutral conditions. Although carbamazepine molecule acts like neutral component, according to obtained results, the maximum removal efficiency (85%) was achieved in base medium, at pH 9. After performed the first set of experiments, pH 9 was adopted as optimal.

Influence of mass dosage
It is necessary to investigate what is the optimal mass of activated carbon in order to achieve satisfactory removal efficiency. By increasing the amount of activated carbon, the number of available sorption sites on its surface area will increase causing increase in removal efficiency. Figure 2. shows the impact of activated carbon dosage on CBZ adsorption.

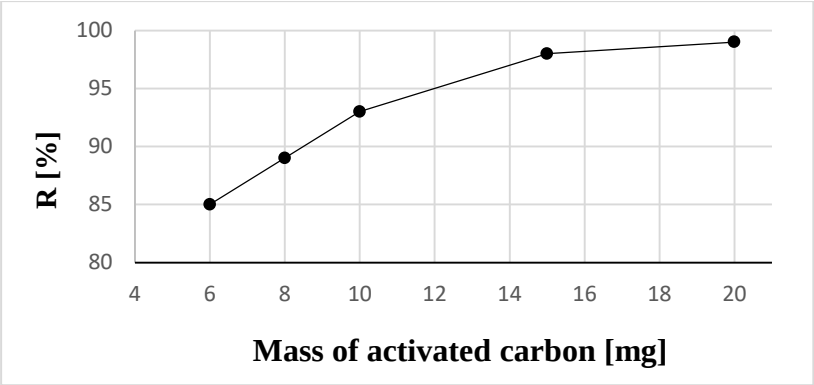


Figure 2. The influence of activated carbon mass

According to Figure 2. the maximum removal efficiency was archived at 20 mg dosage. For further investigation, 10 mg of activated carbon was used as optimal mass of AC.

Influence of contact time

The time in which activated carbon and target pollutant are in contact is essential for the theoretical modeling which can explain the nature of the adsorption process. Figure 3. shows the effect of contact time on CBZ adsorption. Contact time of 30 min was used as optimal for adsorption of CBZ on AC.

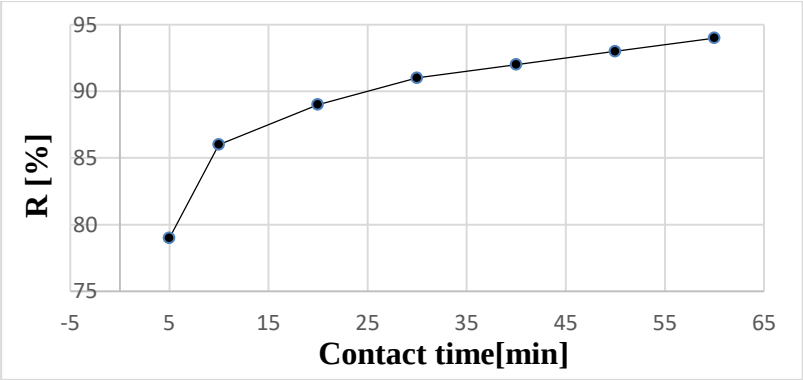


Figure 3. The influence of contact time

Conclusion

The possibility of applying the adsorption for removal of one of the most persistent organic microcontaminants in water matrices, carbamazepine, was investigated. The obtained results revealed that adsorption onto the commercially available activated carbon Norit SA2 are effective for the removal of anti – epileptic drug - carbamazepine from water. According to provided experiments, pH value of 9, mass of 10 mg, contact time of 30 minutes are the most suitable for efficient CBZ removal. The CBZ adsorption is explained by chemisorption which involves chemical reaction between surface and adsorbate. Pharmaceutical products and their degradation products are increasingly detected in the environment and still their fate and transformation pathways are largely unknown. The further development of effective methods for removal of pharmaceuticals will be a great challenge.

Acknowledgements

This study has been supported by Projects of Ministry of Education, Science and Technological Development, Republic of Serbia (Project III46009 and Project TR34014) and Project of the Government of Vojvodina “Synthesis and application of new nanostructured

materials for the degradation of organic pollutants from municipal landfill leachate in Vojvodina“, no. 114-451-1821/2016-03.

References

[1] Baghdadi, M., Ghafari, E., Aminzadeh, B., Removal of carbamazepine from municipal wastewater effluent using optimally synthesized magnetic activated carbon: Adsorption and sedimentation kinetic studies, in Journal of Environmental Chemical Engineering, No. 4, 2016, pp 3309 – 3321.
[2] Stackelberg, P.E., Furlong, E.T., Meyer, M.T., Zaugg, S.D., Henderson, A.K., Reissman, D.B., Persistence of pharmaceutical compounds and other organic wastewater contaminants in a conventional drinking-water-treatment plant, in Science of The Total Environment, No. 329, pp 99–113.
[3] Alonso, S.G., Catala, M., Maroto, R.R., Gil, J.L.R., Gil de Miguel, A., Valcarcel, Y., Pollution by psychoactive pharmaceuticals in the Rivers of Madrid metropolitan area (Spain), in Environmental International, No. 36, 2010, pp 195 – 201.
[4] Cabrera – Lafaurie, W.A., Roman, F.R., Hernandez – Maldonado, A.J., Removal of salicylic acid and carbamazepine from aqueous solution with Y-zeolites modified with extraframework transition metal and surfactant cations: Equilibrium and fixed-bed adsorption, in Journal of Environmental Chemical Engineering, No. 2, 2014, pp 899 – 906.
[5] Novaković, M., Pap, S., Bežanović,V., Mihajlović, I., Đogo, M., Radonić, J., Turk Sekulić, M.: Efficacy Evaluation of Biosorption of Anti - Epileptic Drug –Carbamazepine onto Low – Cost Adsorbent Prepared From Apricot Stones, in Proceedings of the IWA 8th Eastern European Young Water Professionals Conference, Gdansk, Poland, 2016, pp. 234 – 240.
[6] Rivera – Utrilla, J., Sanchez – Polo, M., Ferro – Garcia, M.A., Prados – Joya, G., Ocampo – Perez, R., Pharmaceuticals as emerging contaminants and their removal from water. A revie, in Chemosphere, No. 93, 2013, pp 1268 – 1287.
[7] Kleywegt, S., Pileggi, V., Yang, P., Hao, C., Zhao, X., Rocks, C., Thach, S., Cheung, P., Whitehead, B., Pharmaceuticals, hormones and bisphenol A in untreated source and finished drinking water in Ontario, Canada — Occurrence and treatment efficiency, in Science of The Total Environment, No. 409, 2011, pp 1481 – 1488.
[8] Calisto, V., Ferreira, C.I.A., Oliveira, J.A.B.P, Otero, M., Esteves, V.I., Adsorptive removal of pharmaceuticals fromwater by commercial and waste-based carbons, in Journal of Environmental Management, No. 152, 2013, pp. 83 – 90.
[9] Nadaroglu, H., Kalkan, E., Demir, N., Removal of copper from aqueous solution using red mud, in Desalination, No. 251, 2010, pp 90 – 95.
[10] Tahir, S.S and Rauf, N., Removal of a cationic dye from aqueous solutions by adsorption onto bentonite clay, in Chemosphere, No. 63, 2006, pp 1842 – 1848.
[11] Yuan, S., Jiang, X., Xia, X., Zhang, H., Zheng, S., Detection, occurrence and fate of 22 psychiatric pharmaceuticals in psychiatric hospital and municipal wastewater treatment plants in Beijing, China, in Chemosphere, No. 90, 2013, pp 2520 – 2525.
[12] Dhodapkar, R., Rao, N.N., Pande, S.P., Kaul, S.N., Removal of basic dyes from aqueous medium using a novel polymer: Jalshakti, in Bioresource Technology, No. 97, 2006, pp 877 – 885.