



Phenol Removal from Aquatic Solution Using Three Carbon Nanostructured Adsorbents: Investigation of the Effective Parameters and Adsorption Kinetic

Eisa Solgi¹, Akram Hosseinnia^{1,2*}, Saeideh Tasharrofi², and Hossein Taghdisian²

1. Faculty of Natural Resources and Environments, Malayer University, Hamedan, Iran

2. Environment and Biotechnology Division, Research Institute of Petroleum Industry (RIPI), Tehran, Iran

Hosseinniaa@ripi.ir

DOI: 10.22078/pr.2018.3346.2542

Received: June/13/2018

Accepted: August/04/2018

INTRODUCTION

Phenol is one of the benzene derivatives found in industrial waste waters. Due to its carcinogenicity, high toxicity, high ecological damage and low biodegradability, its elimination from the environment is required. Moreover, among different methods and technologies, adsorption process is used due to high efficiency, lower cost and suitable selectivity [1, 2]. In the present study, the investigation and synthesis of Graphene, Carbon mesoporous (CMK-3) and Multi-wall carbon nanotube (MWCNT), as well as their removal efficiency have been investigated. In this regard, the effect of pH, adsorbent loading and contact time were considered. Also, three different kinetic adsorption models i.e. pseudo-first order, pseudo-second order and the Elovich model were studied.

MATERIALS AND METHODS

The materials used in the present work are Tetraethyl orthosilicate, Glass water, Cetyl trimethyl ammonium bromide, Graphite, Sulfuric acid, Methane, Sucrose, Hydrochloric acid, Hydrofluoric acid, Sodium hydroxide, Isopropyl alcohol, Copolymer P123, and Phenol.

Also, several techniques such as X-ray diffraction (XRD), Brunauer–Emmett–Teller (BET) and Scanning electron microscope (SEM) were used for nano-adsorbent characterization.

PARAMETERS

In this study, pH, Adsorbent loading and contact time as affecting factors were investigated. In this regard, pH in the range of 2 to 12, with step 2, the concentration of adsorbent in the range of 0.1 to 1.5 g/l with step of 0.1 and time in the range of 0 to 120 minutes were considered.

Since the purpose of this study is the practical application of adsorbents at ambient temperature, all experiments have been carried out at room temperature. In order to ensure the accuracy of the results, the adsorption experiments were repeated three times, and mean values were reported as the final results. Furthermore, adsorption kinetic isotherm models were performed in pH 2, 4, 6, 8, 10, and 12 while adsorbent loading and phenol initial concentration were 0.5 g/l and 100 ppm respectively.

RESULTS AND DISCUSSION

EFFECT OF PH

The pH of the solution is one of the most important parameters in the adsorption process. The effect of pH is controlled by two factors, i.e. Point of zero charges (pHpzc) and Acid dissociation constant (pKa) of phenol [3]. The pHpzc values for graphene, CMK-3, and MWCNT adsorbents are 7, 4.3, and 6 respectively [4-6] whereas the phenol dissociation constant (pKa) is 9.89. The optimum pH for phenol adsorption by the all adsorbents was 8 in which the optimum pH is in the range of $pH_{pzc} < pH < pK_a$ where the electrostatic forces between adsorbents and contaminant act as the attraction, and therefore the efficiency of the adsorption process is high.

EFFECT OF ADSORBENT DOSE

In order to investigate the effect of adsorbent loading in the adsorption process, the amount of adsorbent was changed in the range of 0.1 to 1.5 g/l. As shown in Fig. 1, the maximum efficiency for graphene, CMK-3, and MWCNT is 24%, 92% and 32% respectively. However, with increasing adsorption dose, the rate of phenol uptake has a

decreasing trend (Fig. 2).

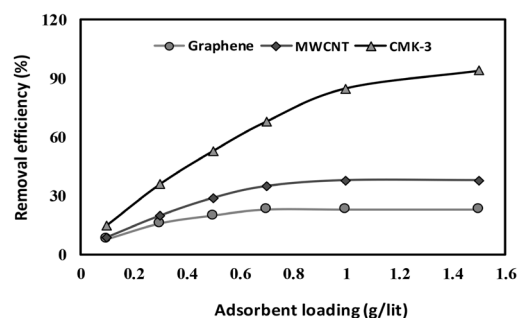


Figure 1: Effect of adsorbent loading on adsorption efficiency.

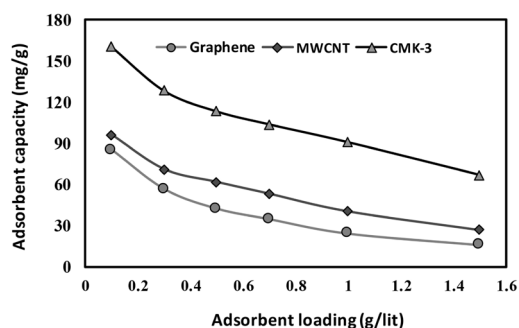


Figure 2: Effect of adsorbent loading on adsorption capacity.

CONTACT TIME EFFECT

Based on the obtained results, for all of the adsorbents, the optimum time for saturation of active sites is about 40 minutes and giving extra time will not substantially change the process efficiency.

Kinetics models for phenol adsorption

The results show that for all of the three adsorbents, the pseudo-second-order model is the most appropriate. Also, the correlation coefficient values (R²) of this model for graphene, CMK-3, and MWCNT adsorbents are 99/99, 99/6 and 98/9 respectively.

CONCLUSION

The results showed that increasing the amount of adsorbent leads increases the adsorption efficiency whereas the adsorption capacity

decreases, which the trends in both cases are nonlinear. Furthermore, the highest removal for graphene, MWCNT and CMK-3 was observed in pH 8. It was also found that for all three adsorbents, optimum contact time to saturate active sites is about 40 minutes, and more contact time does not change the process efficiency. Finally, based on the obtained results, for all adsorbents, pseudo second order model fitted better the experimental data than Pseudo first order and Elovich kinetic models. The results showed that the CMK-3, which has been used in the present study, has the highest performance in phenol removal from water due to its higher yield and efficiency as well as the appropriate price.

REFERENCE

- [1]. Kakavandi B., Rezaee Kalantari M., Ahmadi E., Rastkari N., Fatehi M. and Azari A., "Synthesis and efficiency evaluation of magnetic nanocomposite of activated carbon- zero valent iron/silver (PAC-Fe⁰/Ag) in phenol removal from aqueous solution," Iranian Journal of Health and Environment, Vol. 7, No. 3, pp. 399-412, 2014.
- [2]. Kilic M., Apaydin-Varol E. and Pütün A. E., "Adsorptive removal of phenol from aqueous solutions on activated carbon prepared from tobacco residues: Equilibrium, kinetics and thermodynamics," Journal of Hazardous Materials, Vol. 189, Issues 1-2, pp. 397-403, 2011.
- [3]. Liu, Q. S., Zheng T., Wang P., Jiang J. P. and Li N., "Adsorption isotherm, kinetic and mechanism studies of some substituted phenols on activated carbon fibers," Chemical Engineering Journal, Vol. 157, Issues 2-3, pp. 348-356, 2010.
- [4]. Abdel Ghani N. T., El-Chaghaby G. A. and Helal F. S., "Individual and competitive adsorption of phenol and nickel onto multiwalled carbon nanotubes," Journal of advanced research, Vol. 6, No. 3, pp. 405-415, 2015.
- [5]. Ezzeddine Z., Batonneau-Gener I., Pouilloux Y. and Hamad H., "Removal of methylene blue by mesoporous CMK-3: Kinetics, isotherms and thermodynamics," Journal of Molecular Liquids, Vol. 223, pp. 763-770, 2016.
- [6]. Zuccaro L., Krieg J., Desideri A., Kern K. and Balasubramanian K., "Tuning the isoelectric point of graphene by electrochemical functionalization," Scientific reports, Vol. 5, p. 11794, 2015.