Removal of Styrene Contaminant in Petroleum Ether 40-60 by Adsorption on Activated Carbon

Kawinna Wongyaeng[1], Rungnapha Phaethaisong[1], Nicharee Kliniam[2], Titikan Somboon[1] and Wimonrat Tongpoothorn[1]*

[1]Department of Chemistry, Faculty of Engineering, Rajamangala University of Technology Isan, Khon Kaen Campus, Khon Kaen, 40000 Thailand

[2]RCI Labscan Limited, Bangthorat, Mueang Samut Sakhon, Samut Sakhon, 74000 Thailand

*Corresponding Author: Wimonrat.to@rmuti.ac.th

Received 3 January 2025; Received in revised form 24 May 2025; Accepted 1 June 2025

Abstract

The removal of contaminants in petroleum ether 40-60 with an adsorption method using 9 types of activated carbon (AC) was investigated. The optimum condition was achieved by varying the types of AC, ratios between solvent volume to AC amount, and adsorption time. The GC-FID results reveal that the main impurity in petroleum ether 40-60 is styrene. By using activated carbon type BITU8x30 with a ratio of 900L:135Kg and adsorption time of 24 hours, styrene was removed up to 98.43%. The purification of petroleum ether 40-60 was also confirmed by UV-visible spectrometry. This adsorption method provides efficiency, cost effectiveness and low energy consumption. Moreover, this proposed method can reduce time and steps of petroleum ether 40-60 purification in industrial scale as well.

Keywords: Adsorption; Activated carbon; Purification; Organic solvent

1. Introduction

The purification of organic chemicals depends on the nature of the compounds and the impurities in them. Generally, various methods can be used for purification of organic compounds, such as filtration [1], distillation [2], chromatography [3]. The organic solvent named petroleum ether 40-60 is mostly used by pharmaceutical companies and in the manufacturing process. It is a lightweight hydrocarbon used chiefly as a nonpolar solvent. The requirement for petroleum ether in laboratory uses as solvent and extraction solvent is analytical grade (AR). Thus, purification of petroleum ether is required.

Recently, adsorption is one of the effective methods for removal pollutant [4-7]. The method provides simplicity, cost-effectiveness, and high efficiency. Activated carbon (AC) is porous, inexpensive and readily available for use as adsorbents. It is widely used as an adsorbent in wastewater treatment because of its high adsorption capacities, extremely high surface areas, micropore volumes, and fast adsorption. The adsorption of organic solvents, such as styrene [8] toluene [9] benzene [10] by activated carbon was reported. Therefore, the adsorption process for removal of contaminates in petroleum ether is considered promising as described above. Therefore, the different types of commercial AC, the ratio of solvent volume to adsorbent, and adsorption time were investigated to obtain the optimized condition for purification of petroleum ether in industrial scale.

2. Experiments

2.1 Chemicals and instruments

Nine types of commercial AC (COCONUT, HRLC-105, BITU, BITU8x30, BITU12x40, GB1000, HR1240, YL-303, HRCS1240) were purchased. Raw material of petroleum ether 40-60 was obtained from RCI Labscan. The amount of contaminated styrene was detected by UV-Visible Spectrophotometer with single beam (Agilent Technology, UV8453) and Gas Chromatograph-Flame Ionization Detector (GC-FID) (Agilent Technology, 7890A).

2.2 Adsorption processes

The removal of styrene in raw material of petroleum ether 40-60 (RM) was carried out by batch reactor. The 9 types of commercial AC (COCONUT, HRLC-105, BITU, BITU8x30, BITU12x40, GB1000, HR1240, YL-303, HRCS1240) were employed as adsorbent. The volume of RM was fixed at 50 mL. The adsorbent was varied (2.5, 5.0 and 7.5 g), corresponding to the ratio of 900L:45kg, 900L:90kg and 900L:135kg, respectively. The adsorption time was also investigated (4, 8 and 24 hours). The removal of styrene contaminated in RM was detected by GC-FID and UV-Visible spectrophotometry.

3. Results and discussion

Fig. 1 presents raw material of petroleum ether 40-60 chromatogram. The experimental results confirm that RM is mainly contaminated with styrene as seen at the retention time of about 8.6 min. The presence of styrene in the solvent (RM) results in a clearly intense odor. Therefore, removal of it to purify the RM is required.

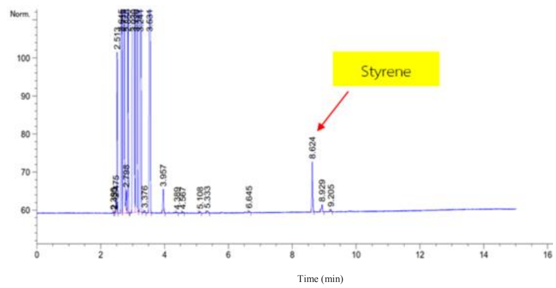


Fig. 1 Chromatogram of raw material of petroleum ether 40-60 contaminated with styrene.

Styrene's removal from petroleum ether 40-60 was examined using various AC types, solvent to adsorbent ratio and adsorption times. As shown in Fig. 2, the results show that the amount of styrene decreases with adsorption time. The lowest amount was found at 24 h. The results also present that the removal of styrene increases with increasing the ratio between solvent volume to AC amount. Its results from the increases of total surface area to adsorb styrene on its surface. According to the findings, bituminous AC type can lower styrene levels more effectively than other types.

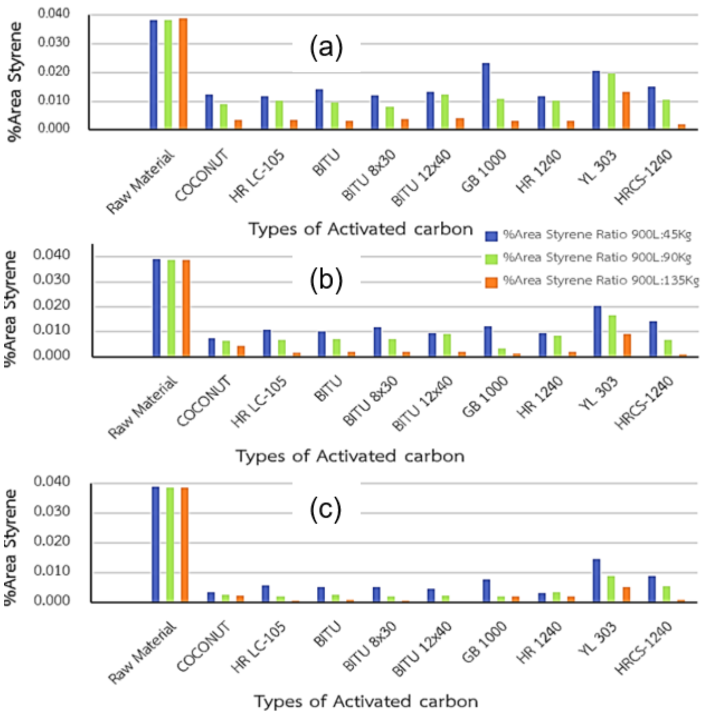
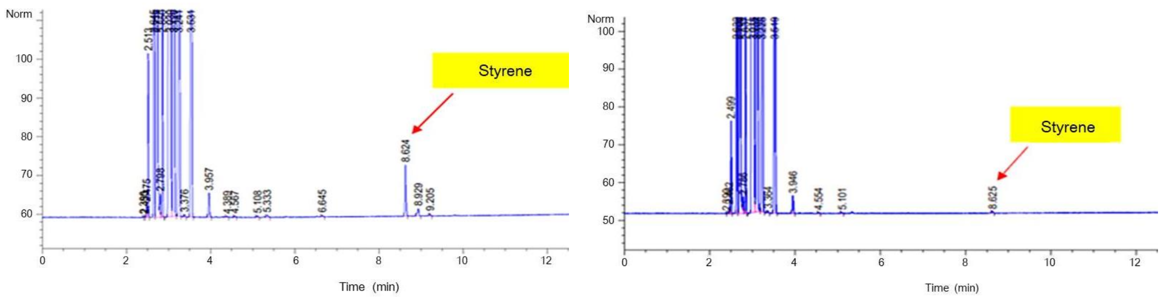


Fig. 2 Adsorption of styrene by different types of activated carbon with various ratio. (a), (b) and (c) present adsorption under 4, 8 and 24 hours, respectively.



(a) (b)

Fig. 3 Chromatogram of petroleum ether 40-60 under the condition without adsorption (a) and with adsorption by BITU8X30 (b).

Table 1. Removal efficiency of styrene under adsorption by different types of AC

Adsorption time	%Removal of each AC type								
	Coconut	HR LC-105	BITU	BITU 8x30	BITU 12x40	GB 1000	HR 1240	YL 303	HRCS-1240
4	90.82	91.15	86.82	86.76	88.33	80.08	91.80	62.17	77.59
8	88.96	94.53	93.06	94.99	93.83	94.63	91.31	77.27	85.66
24	94.30	98.27	98.04	98.43	97.59	94.71	95.07	87.05	98.09

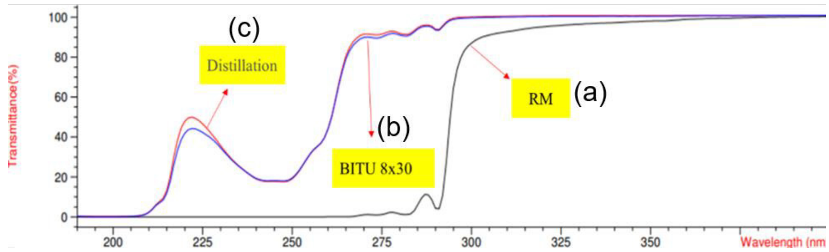


Fig. 4 UV-Visible spectra of Petroleum Ether 40-60 in case of (a) raw material, (b) under the adsorption by AC (BITU8X30) and (c) distillation.

The removal efficiency was evaluated by using equation as follows:

$$\%Removal = \frac{A_0 - A}{A_0} \times 100$$

Where A_0 and A are the %peak area of styrene before and after adsorption.

The removal efficiency was summarized in Table 1. All types of AC can remove more than 85% styrene within 24 hrs. Moreover, the ratio of 900 L to 135 kg of BITU8X30 shows the highest removal efficiency (98.43%). Therefore, this is the best condition for removal of styrene from raw material of petroleum ether 40-60.

BITU8x30 activated carbon is produced from bituminous coal containing 80 – 90 % of carbon content [11]. Also, it has high density and low moisture content, so it's effective in high absorption of aromatic compounds. The interaction between AC with styrene would be the Van der Waals forces of nonpolar molecules, specifically London dispersion forces [8-10]. Also, the porous structure provides numerous sites where styrene molecules can physically adsorb onto the carbon surface.

The styrene removal was again confirmed by the GC results as shown in Fig.3. The results show that styrene is totally removed, indicated by reduction of the styrene peak. This insists that the designed adsorption process for styrene removal can be successfully done. UV-VIS technique is also employed to analysis purity of ย petroleum ethers 40-60 solvent (RM). As shown in Fig.4, the transmittance at the wavelength between 210-250 nm increases, confirming that the RM is purified by the adsorption by AC. Moreover, the experimental results showed that the purity of the solvent treated with activated carbon adsorption was comparable to that obtained through distillation.

4. Conclusion

The removal of styrene from petroleum ether 40-60 raw material by the adsorption with AC is successful. The purity of the solvent through AC adsorption provides efficiency comparable to that of the distillation process. However, adsorption presents simplicity, low energy consumption, and cost effectiveness. Moreover, this research shows the first time of using new method for solvent purification based on adsorption instead of distillation (conventional method) in industry.

5. Acknowledgement

This research project is supported by Faculty of Engineering, Rajamangala

University of Technology Isan, Khon Kaen campus (RMUTI.KKC). Authors thanks RCI Labscan. Ltd. company for supporting students in the Cooperative and Work Integrated Education (CWIE) Program.

6. References

[1] Ursino, C., Simone, S., Donato, L., Santoro, S., De Santo, M. P., Drioli, E., Di Nicolòb, E., and Figoli, A. (2016). ECTFE membranes produced by non-toxic diluents for organic solvent filtration separation, *RSC Advances*, vol. 6, pp. 81001-81012.

[2] Gupta, O., Roy, S., and Mitra, S. (2018). Enhanced membrane distillation of organic solvents from their aqueous mixtures using a carbon nanotube immobilized membrane, *Journal of Membrane Science*, vol. 568, pp. 134-140.

[3] Wagenaar, F. L., Hochlowski, J. E., Pan, J. Y., Tu, N. P., and Searle, P. A. (2009). Purification of high-throughput organic synthesis libraries by counter-current chromatography, *Journal of Chromatography A*, vol. 1216, pp. 4154-4160.

[4] Gonzalez-Serrano, E., Cordero, T., Rodriguez-Mirasol, J., Cotoruelo, L., Rodriguez, J. J. (2009). Removal of water pollutants with activated carbons prepared from H_3PO_4 activation of lignin from kraft black liquors, *Water Research*, vol. 38, pp. 3043-3050.

[5] Mariana, M., Abdul Khalil H. P. S., Mistar, E. M., Yahya, B. E., Alfatah, T., Danish, M., Amayreh, M. (2021). Recent advances in activated carbon modification techniques for enhanced heavy metal adsorption, *Journal of Water Process Engineering*, vol. 43, pp. 102221.

[6] Zhang, Z., Wang, T., Zhang, H., Liu, Y., Xing, B. (2021). Adsorption of Pb(II) and Cd(II) by magnetic activated carbon and its mechanism, *Science of The Total Environment*, vol. 757, pp. 143910.

[7] Wang, H., Li, Z., Yahyaoui, S., Hanafy, H., Seliem, H. K., Bonilla-Petriciolet, A., Dotto, G. L., Sellaoui, L., Li, Q. (2021). Effective adsorption of dyes on an activated carbon prepared from carboxymethyl cellulose: Experiments, characterization and advanced modelling, *Chemical Engineering Journal*, vol. 417, pp. 128116.

[8] Isinkaralar, K., Mamyrbayeva, K., Bandegharaei, A. H. (2023). Adsorption of gas styrene on activated carbon from agro waste of Silybum marianum L. as a sustainable precursor, *Biomass Conversion and Biorefinery*. vol. 13, pp. 1-12.

[9] Wibowo, N., Setyadhi, L., Wibowo, D., Setiawan, J., Ismadji, S. (2007). Adsorption of benzene and toluene from aqueous solutions onto activated carbon and its acid and heat treated forms: Influence of surface chemistry on adsorption, *Journal of Hazardous Materials*. vol. 146, pp. 237-242.

[10] Mataji, M., Khoshandam, B. (2014). Adsorption of Benzene on activated carbon from Agricultural waste materials. *Chemical Engineering Communications*. vol. 201, pp. 1294-1313.

[11] Sadasivam, S., Masum, S., Chen, M., Stanczyk, K., Thomas, H. (2022). Kinetics of Gas Phase CO_2 Adsorption on Bituminous Coal from a Shallow Coal Seam. *Energy Fuels*. vol. 36, pp. 8360-8370.