ADSORPTION OF TOLUENE VAPOUR ON ACTIVATED CARBON FIBRE

Hua-Cun Huang[1], Xiao-Ping Zhang[1]*, Zhi-Hui Wang[1], Shui-Xie Chen[2]
1. *Evironmental Science & Enineering Department, South China University of Technology, Guangzhou 510641*
2. *Material Science Institute, Zhongshan University, Guangzhou 510275*

Corresponding author e-mail address: eezxp@163.com

Introduction

Because activated carbon fibres (ACFs) possess significant amounts of micropores, they can have a specific area of up to 2600 m^2/g, and micropore volume of 1.23cm^3/g, which exhibit a higher adsorption capacity and have faster adsorption kinetics than granular activated carbon (GAC) [1]. So little amounts of product are required in industrial applications where pressure drop, which is a fundamental parameter, can be kept to a minimum [2]. And filters made of ACFs tend to have a long operating life. Moreover, ACFs are easier to use than GAC since they can be formed in various forms of cloth, felt, etc. All these features increase the efficiency of the adsorption bed and lead to simplifications in the design and in the size of regeneration units. Therefore, activated carbon fibers are more suitable as an adsorbent for environmental pollution control.

The aims of our research are to study the characteristics of adsorption and desorption of toluene onto series different ACFs and GAC. This paper described the dynamic behaviours of the adsorption of toluene vapour by viscose rayon-based ACF, studied adsorption and desorption performance of toluene vapour on viscose rayon-based ACF and the influence of adsorption performance by many factors. And an experimental dynamic toluene vapour generation system has been developed in order to test viscose rayon-based ACF material. The effect of the specific surface, hole volume, hole diameter, distribution of hole, toluene vapour's concentration, temperature, pressure, velocity of flow, the form of reactor on the equilibrium adsorption capacity and the adsorption kinetics for the toluene will be investigated. The best parameters will be determined and the economic benefit will be evaluated too.

Experimental

The efficiency of the toluene removing system incorporating adsorptive material depends on a number of parameters such as filling density and gas concentration and velocity, adsorptive temperature and so on. The influence of each of these parameters on adsorption capacity was studied.

Besides the parameters mentioned above, we paid more attention to the breakthrough times for the ACF packed bed. And we expected that it could be consistent with the trends observed with the adsorption isotherms [3].

One kind of viscose rayon-based ACF samples with large specific surface areas were used and denoted as ACF. The microstructure of viscose-based ACF was studied. The

crystal structure was analyzed by X-ray diffraction. ACF being graphitoid micro-crystal structure was proved by XRD, and the crystal parameters were calculated. Morphology of viscose fiber and ACF were observed by scanning electron microscope (SEM). Pore structure parameters were studied by BET method. The characteristic parameters of ACF are showed in Table 1. 92 % of pore size is less than 2 nm. Toluene vapors were selected as the adsorbate. High purity nitrogen was used to blow toluene to the required concentration.

Table 1. Physical parameters of viscose rayon-based ACFs

Sample	Surface area (m^2/g)	Wo (ml/g)	$E_{nitrogen}$ (KJ/mol)	Pore width (Å)
viscose rayon-based ACF	1917	0.796	6.08	14.3

The schematic experimental flow diagram was shown in Fig.1.
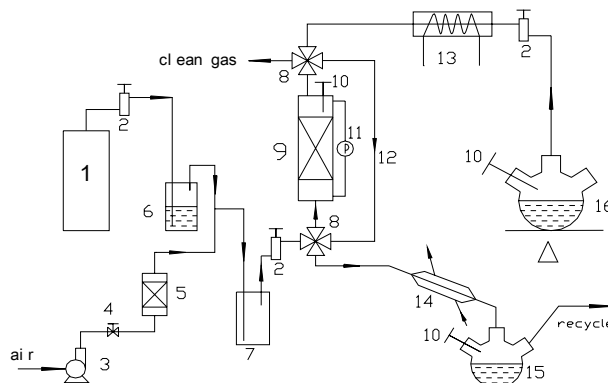
1.High-purity nitrogen; 2. Rotameter flowmeter; 3. Air pump; 4. Adjusting valve; 5.Silicagel desiccator; 6.toluene generator; 7.Mixer; 8.cross valve; 9. Adsorber; 10.Thermometer; 11.Piezometer; 12. Bypass; 13.Heater; 14.Orbicular cooler; 15、16.Three-mouth flask

Fig.1. Schematic diagram of the setup used for the fixed-bed adsorption and desorption studies.

It indicated that the experimental flow was mainly composed of three principal components: The gas generation system, the adsorptive system and the regeneration system. The gas generation system used to afford the test gas upstream of the test material. Nitrogen gas was passed through the bottles for the saturation process, while its flow rate was controlled by rotameter flowmeter. Finally, dilution gas mixing chamber ensure that the test gases were mixed prior to arriving at the inlet of the adsorber where the ACFs was located. The adsorption device was a 30-cm long, 25-mm inside diameter glass pipe. The ACFs were initially dried overnight at 120℃ and then packed in the adsorber. The column temperature was steadied. The gas flow rate was controlled with adjusting valve. The gas inlet was switched to test gas after dried air outgassing for 20 minutes. The relative concentration was controlled by regulating the ratio of the nitrogen flow rate through toluene generator to the overall flow rate. And clear water vapour in high temperature was used to desorb. A GC 900 was used to analyze the influent and effluent gas concentration.

Results and Discussion

Fig.2-4 showed the adsorption curves of toluene in packed beds under different concentrations and velocity with the same bed mass, 1.5000g, 2.5000g and 1.0000g respectively. The concentration of effluent increased gradually with time in the case of ACFs at all inlet concentrations. Moreover, the breakthrough curves became steep slowly with low inlet concentrations.
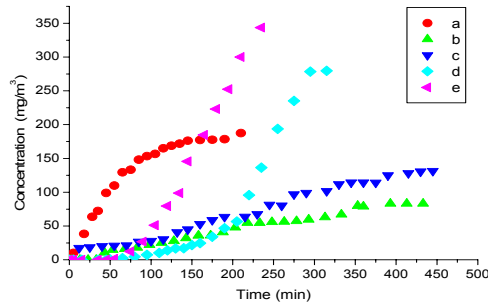
a.200mg/m^3,0.68m/s, 1.5000gACFs, 7cm, 294K; b.150mg/m^3,0.23m/s,1.5000gACFs,7cm,294K; c.90mg/m^3,0.45m/s, 1.5000gACFs, 7cm, 294K; d.280mg/m^3,0.12m/s,1.5000gACFs,7cm,294K; e.360mg/m^3,0.12m/s,1.5000gACFs,7cm,294K

Fig. 2. Adsorption curve of different toluene concentration and velocity

In Fig.2, it was obvious that the breakthrough time of b and c curve was longer than that of a and e curve. This may due to the higher concentrations and velocity of theirs. For d curve, even if its influent concentration was high too, but its velocity of flow was lower than that of b and c curve, so it approximately need the same time (200mins) to reach 60mg/m^3 as b and c's. But after 200 minutes, d curve became steep quickly. Comparing a and e curve, although the concentration of a curve was lower than e's, but the velocity of flow of its was so far higher than e's, so the effluent concentration of a curve increased more quickly. So its curve became steep more quickly during the beginning of adsorbing. For a given ACFs, the longer breakthrough time indicated a greater adsorption capacity. So we could conclude from Fig.2 that the influent concentration and velocity of flow are two important factors that affect the adsorption capacity and we should select a suitable concentration and velocity of flow to adsorb. Both factors must be considered to optimize the adsorbents performance.
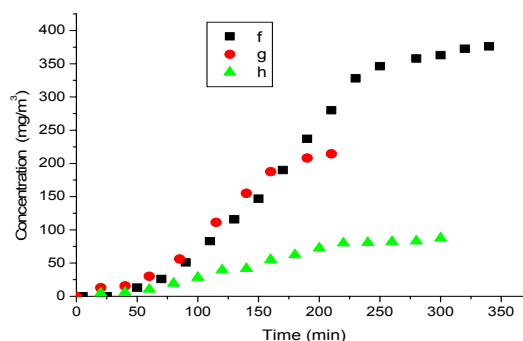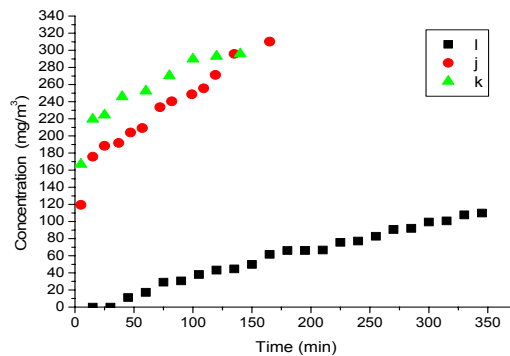

f.450mg/m^3,0.23m/s,2.5000gACFs,294K; g.250mg/m^3,0.45m/s, 2.5000gACFs,294K; h.100mg/m^3,0.68m/s,2.5000gACFs,294K

Fig. 3. Adsorption curve of different toluene concentration and velocity

Comparing the different breakthrough curves in Fig.3 and Fig.4 at different concentration and velocity, it was found that the shorter settle time resulted in shorter

breakthrough time for the influent concentration which was no less than 250mg/m^3. Simultaneously we also found that although the settle time was short enough, ACFs could reach high adsorptive efficiency. Took h curve as an example, because its velocity of flow was faster than f and g, so its settle time was shorter than f and g curves, but its influent concentration was low enough that its breakthrough time was longer than that of f and g curves. On the basis of this we summed up that velocity of ACFs adsorption was so quickly that it could apply in toluene vapour, which was in high velocity and low concentration. But if the concentration of the mixed gas was too high, then we must control the velocity of flow to a lower level in order to attain a longer settle time.

i. 110mg/m^3,0.23m/s, 1.0000gACFs,294K; j. 325mg/m^3,0.45m/s,1.0000gACFs,294K; k. 300mg/m^3,0.68m/s, 1.0000gACFs,294K

Fig. 4. Adsorption curve of different toluene concentration and velocity

It is noted that adsorption is completely reversible upon heating at 100-160℃ thus allowing for recovery and reuse of the adsorbed material. The possible reason is that the regeneration temperature of 100-160℃ is too low to decompose the functional groups, so the ACFs can readsorb to the same capacity during reuse. [4] The correlative desorption curves were showed in the Fig5 and Fig6.
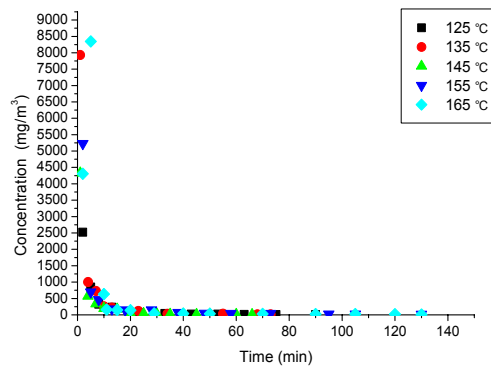

Fig. 5. Desorption curve at different temperature

The effect of temperature on desorption was showed in Fig.5. It illustrated that from 125 ℃ to 165℃, the desorption curves almost had the same track. They almost need 20 minutes to reach 90% desorption rate. The other interesting phenomenon was that the higher desorption temperature, the higher effluent concentration within the beginning 2

minutes. So the higher was the desorption temperature, the quicker was the desorption velocity. This result indicated that the desorption rate was affected by the temperature of water vapour. But the data had approved that the desorption temperature should not higher than 160℃. [4] Because when the desorption temperature was higher than 160℃, the functional groups on the ACFs will be decomposed, which must affect the recycle apply.

The effect of temperature on desorption was also showed in Fig.6. But its temperature was lower than the toluene boiling point(111.6℃). Under this condition, most of the toluene dissolved in the liquor condensate, so the toluene concentration of the effluent gas was low. But it need more time for desorb, so it will produce more waste water. This finding suggests that we should control the desorption temperature within 120~160℃.
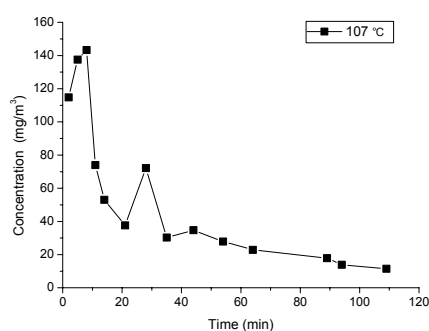

Fig. 6. Desorption curve at 107℃

Conclusions

The test shows that adsorption and desorption performance of toluene vapour by ACFs are related the influent concentration and velocity of flow. Both of them are two important factors that affect the adsorption capacity. Both factors must be considered to optimize the adsorbents performance. It has a high adsorbed capacity and its breakthrough time is long enough under different conditions, although this is dependent on the test conditions. On the other hand, it is very easy to reuse the ACFs. But we should control the desorption temperature within 120~160℃. So we concluded that the viscose rayon-based ACF could be utilized in controlling toluene vapour efficiently.

Reference

[1] E. Vilaplana-Ortego, J. Alcan~iz-Monge, D. Cazorla-Amoro´ s, A. Linares-Solano*. Activated carbon fibre monoliths. Fuel Processing Technology 77–78 (2002) 445– 451.
[2] P Navarri, D Marchal & A Ginestet. Activated Carbon Fibre Materials for VOC Removal. Filtration & Separation (2001)34-41.
[3] Zheng-Hong Huang, Feiyu Kang, Kai-Ming Liang, Jiming Hao. Breakthrough of methyethylketone and benzene vapors in activated carbon fibers beds. Journal of Hazardous Materials B98 (2003)107-115.

[4] Christian L. Mangun, Kelly R. Benak, James Economy, Kenneth L. Foster. Surface chemistry, pore sizes and adsorption properties of activated carbon fibers and precursors treated with ammonia. Carbon 39(2001)1809-1820.