Adsorption of harmful substances by activated carbon from rubberwood

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1. Introduction

In Southeast Asia Countries, rubberwood furniture is one of the important products for exportation. Various forms of residues are discharged from the process of rubberwood manufacturing. In this process, a portion of wood residues are being thrown away to isolated country site or dumping site and are burned illegally. These disposals do cause environmental problems such as accidental forest burning, release of hazardous gases, and soil contamination by toxic preservatives[1]. The preservatives issuing from the steam drying step of the process also pollute river water and so on. Tanjore *et al.* has stated the pentachlorophenol, one of the substances of wood preservative, is highly toxic and can easily diffuse into the environment as wastewater[2]. These problems are considerably serious in these countries.

Wood can be precursor of various kinds of useful materials, *e.g.*, fuel off gas, pyroligneous acid(PA), and activated carbon(AC). PA is studied and widely used as a wood preservative[3,4,5]. Lim *et al.* showed that the rubberwood PA also contained preservative components such as phenols and proposed to use the PA from the residue as a wood preservative in the rubberwood process[5]. On the contrary, these preservative components are harmful as well. AC is well known as a adsorbent to remove unfavorable components from drinking water or so forth and is tried to be prepared from various kinds of raw materials[6,7].

The aim of this thesis was the removal of harmful components contained in the rubberwood pyroligneous acid by adsorption with the AC from rubberwood in order to solve the problems mentioned above. First, the rubberwood sawdusts were carbonized to obtain chars and the chars were activated to ACs under various temperatures. Secondly, the adsorptions of phenols *etc.* by the chars and ACs were studied with model aqueous solution of these components and the real rubberwood PA under various conditions.

2. Experimental

2.1 Preparation of activated carbon from rubberwood

The feed raw material was the sawdust of rubberwood of Malaysia growth. The main part of the reactor employed both for the carbonization and activation was the stainless steel tube measuring 0.035 m in inner diameter and 0.70 m in effective length. This reactor was situated horizontally in an electrical oven. The carbonizations were carried out with 25 to 30 g of the feed sawdust in the temperature range of 470 to 1,300 K for 0.5 hour after reaching respective temperatures. The atmosphere was nitrogen and the flow rate was fixed at 30 m^3/h. Gases, crude pyroligneous acid (CPA), and chars were obtained in this reaction.

The char obtained at 873 K was provided into the activation to give the activated carbon(AC). The feed char of 10 to12 g was activated under 1070 to 1,200 K for 0.5 h in the atmosphere of carbon dioxide where the flow rate was 30 m^3/h.

These chars and ACs were washed with boiling water, pulverized, and sieved into a particle size of 149×10^{-6} to 420×10^{-6} m.

2.2 Adsorption of phenols in model solution and real pyroligneous acid

The adsorbents were the char and AC prepared above. The aqueous model solutions and rubberwood PA were used as feed liquids. CPA was distilled up to 373 K to provide the PA. The CPA was obtained by the above carbonization or from a rubberwood charcoal manufacturing company in Malaysia. The latter CPA was used mainly. **Table 1** gives the compositions of the feed liquids. The phenols etc., generally contained in PA, were selected to be quantified.

A specified amount of the adsorbent (0.1~1.0 g) and that of the feed liquid(2.0×10^{-5}~5.0×10^{-5} m^3) were placed in a conical flask (1.0×10^{-4} m^3). The flask was shaken at constant temperature (303±1 K) with shaking velocity of 5,400 h^{-1} for 120 h. The previously study confirmed the attainment to equilibrium within 92 hour[6].

Table 1 The initial concentration of adsorbates in feed solution

Adsorbates	Initial concentration, C_0 [g/m^3]
Phenol in PA	81~191
Syringol in model solution	782
P-cresol in model solution	655
Phenol in model solution	80~800

3. Results and discussion

3.1 Yields of char and activated carbon

Figure 1 shows the fractional yields of the char[5] and activated carbon(AC) on the basis of the original feed sawdust. The yields of chars decreased with temperature in lower temperature range and was almost constant at 0.2 in the range over 773 K. The yield of the activated carbon decreased with temperature in the range of this work.

3.2 Adsorption of phenols in model solution

Figure 2 shows the adsorptions of syringol, p-cresol, and phenol on the chars obtained from the carbonization at 673, 773, and 873 K (abbreviated to C673, C773, C873). The chars could adsorb these components, although the adsorption by the chars obtained at 1,073 and 1,273 K were not detected. The adsorption amounts of phenol and p-cresol on these three chars were almost equivalent to one another. C873 adsorbed syringol more than the other chars.

The adsorption isotherms of phenol on the chars and activated carbons in the model aqueous solution are presented in **Figure 3**. The result of a commercial activated carbon, FS100[7], was also given in this figure for reference. The AC obtained in this work had comparable or higher adsorption

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capacities than FS100. The adsorption capacity of the char was much lower than those of activated carbons.

3.3 Absorption of phenols in real pyroligneous acid

Figure 4 shows the adsorption isotherms of phenol on the char and AC in the real PA. The AC gave larger adsorption performance than the char similarly to the case in the model solution. The amounts of phenol adsorptions in the PA were small compared to those in the model solution. Since the PA was multicomponent mixture, other components than phenol may also adsorb on the adsorbents competitively and may occupy the adsorption sites.

The removal ratio R was obtained by,

$$R = \frac{C_0 - C_e}{C_0} \qquad (1)$$

where C_0 and C_e were the initial and equilibrium liquid phase concentrations.

The C_0, C_e, and R of phenols in the PA and diluted PA on the AC1073 are summarized in **Table 2**(The ratio of weight of adsorbent to adsorbate is 0.01). The PA was diluted with the equivalent volume of pure water to give the diluted PA. PA even after dilution confirmed to possess preservativity by Lim[5]. The removal ratios, R, of the harmful components in the PA ran into 0.87 averagely (0.77~0.97). These components in the diluted PA could be removed by the AC1073, almost completely. The restriction for the total concentrations of harmful phenols are 1.0 g/m^3 in Malaysia[8] and 5.0 g/m^3 in Japan[9]. The total concentration of the phenols in the diluted PA after adsorption, C_e, was less than 0.8 g/m^3, which was permissible level for the both restrictions.

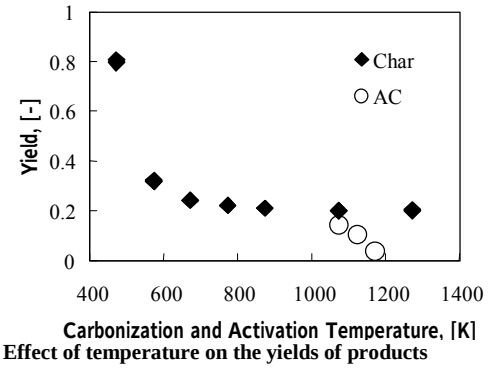

Fig.1 Effect of temperature on the yields of products

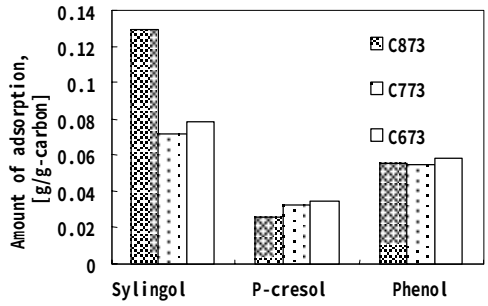

Fig.2 Effect of temperature for adsorption of phenol

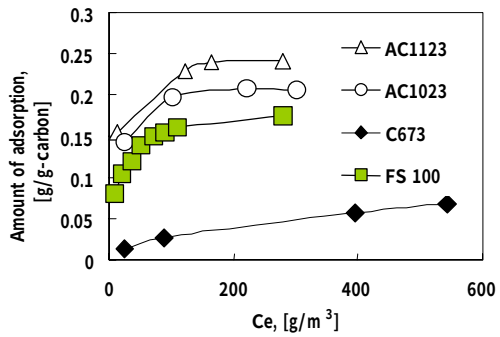

Fig.3 Adsorption isotherms of phenol in model solution at 303K on the different kinds of carbons

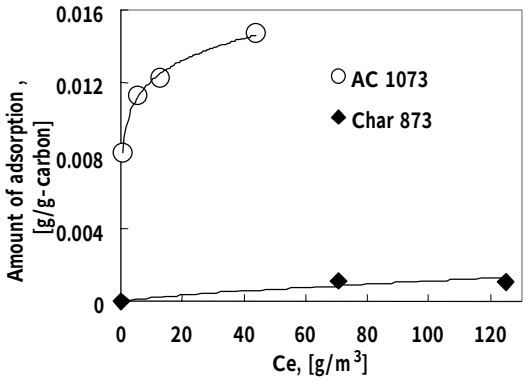

Fig.4 Adsorption of isotherms of phenol in PA at 303K on the different carbons

Table 2 Adsorptions in PA and diluted PA at 303K on the AC1073

Component	PA			diluted PA		
	C_0 [g/ m^3]	C_e [g/ m^3]	R [-]	C_0 [g/ m^3]	C_e [g/ m^3]	R [-]
guaiacol	305	46	0.84	131	<0.1	>0.999
p-cresol	40	1.6	0.96	13	<0.1	>0.999
m-cresol	59	3.2	0.95	22	<0.1	>0.999
sylingol	182	4.8	0.97	73	<0.1	>0.999
phenol	191	43	0.77	82	0.4	0.995
total	777	98.6	0.87	321	<0.8	0.998

4. Conclusion

Whereas chars from rubberwood had poor adsorption capacities for phenols, the capacities were remarkably improved by the activation with carbon dioxide. The capacities of these activated carbons were comparable with that of the commercial activated carbon. The phenols in the diluted PA, which would be used as a wood preservative, could be removed to the permissible levels as those in wastewater by the adsorption with the rubberwood activated carbon. This method was proposed as a solution for the problems in furniture process in Southeast Asian Countries.

Acknowledgement

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