Experimental Study on VOC Removal Performance of Nonwovens Cultivated Carbon

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ABSTRACT

The objective of this paper is to investigate volatile organic compound (VOC) removal performance of nonwovens cultivated carbon obtained from carbonizing and activating nonwovens made of fibrous waste by experiments for healthy and sustainable buildings. The experiments to identify the removal performance under the static and dynamic conditions supposed to be used as interior finishing material and air filter of air cleaner respectively were done. As a result of experiments for nonwovens cultivated carbon sheets with different BET specific surface using a small chamber, high removal efficiencies for VOC gases such as *toluene, xylene* and *styrene* were obtained. The removal performance under the static condition was relatively stable regardless of the specific surface. On the other hand, the removal efficiency of the present air filter under the dynamic condition ranged from 20 to 40%, and decreased as the specific surface increased.

KEYWORDS: IAQ, Nonwovens cultivated carbon, Removal efficiency, VOC

1. INTRODUCTION

A large quantity of textile has been used not only for clothes or industrial products, but also for building materials such as interior finishing, curtain, carpet and so on. In 2003, only 10 % out of two million tons per year was recycled in Japan. Therefore proper treatment for tons of fibrous waste generated from the production or disposal process is required to reduce, reuse and recycle the waste for reducing the environmental loads. In recent years, a new technology to produce nonwovens cultivated carbon made from the fibrous waste, which has excellent removal performance of gaseous chemical contaminants, has been developed. Cultivated carbon filter has been recognized as one of efficient adsorption materials to remove chemical contaminants as well as source control and ventilation strategies in rooms. The nonwovens cultivated carbon filter is obtained from carbonizing and activating nonwovens made of fibrous waste including Polyacrylo Nitorile (PAN). It has numerous very fine holes to adsorb chemical contaminants, and the pore size can be changed according to the burning temperature and the activate treatment.

Many studies on VOC removal performance of building materials with sorption effect such as zeolite, porous ceramic material and so on have been reported. For example, Aguado et al. (2004) studied on the removal of pollutants from indoor air using zeolite membranes, and showed that it can be used successfully to remove VOCs from indoor air at very low concentration levels.

Tang (2002) reported the latest chemical air filters for VOC and Aldehydes that are activated carbon filter, photocatalysis filter and catalysis filter. The gas removing mechanism, gas removal efficiency, gas removing capacity, pressure loss and matters that require attention for filter selection, installation and operation, were introduced and evaluated.

Huang et al. (2003) investigated that the breakthrough of low concentration methyethylketone (MEK) and benzene vapors in bed packed with rayon-based carbon fiber (ACF) with different specific surface areas, and concluded that the breakthrough adsorption indicates that ACF, with an appropriate surface area, could be utilized on controlling VOCs in indoor air.

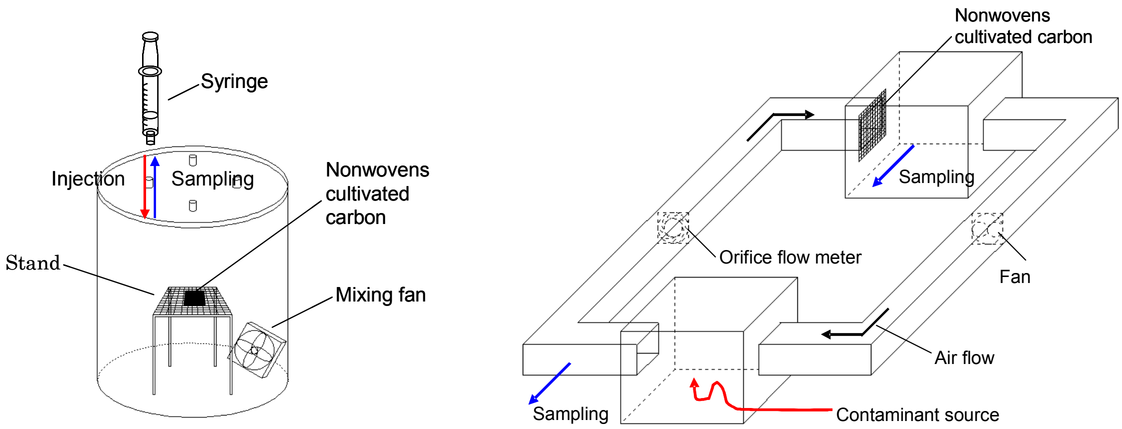
Ao et al. (2005) evaluated the pollutant removal efficiency of a commercial air cleaner installed with a TiO_2 filter and a TiO_2 immobilized on activated carbon (TiO_2/AC) filter inside an environmental chamber, and showed significant removal efficiency of TiO_2/AC filter.

However a few researches have been concentrated on cultivated carbon sheet as interior finishing material or filter of air cleaner to remove chemical contaminants and control indoor air quality. The objective of this paper is to investigate VOC removal performance of nonwovens cultivated carbon by experiments for healthy and sustainable buildings. The experiments to identify the removal performance under the static and dynamic conditions supposed to be used as interior finishing material and air filter of air cleaner respectively were done.

2. METHOD

Outline of the static measurement to investigate the removal performance of nonwovens cultivated carbon is shown in Figure 1(a). A small piece of nonwovens cultivated carbon sheet, 2cm by 2cm (4 cm^2), was put on the stand inside a small chamber made of stainless steel with the volume of 10L. The chamber was installed in a constant temperature installation to control the inside air temperature. A small volume of *toluene* gas was injected by a syringe, and the inside air was mixed well by a small mechanical fan for five minutes, then a small volume of air inside the chamber was sampled by the other syringe after 30 minutes, 1, 2 and 4 hours from the beginning time. Then the sample air was analyzed by a gas chromatography (New COSMOS Electric Co. XG-100V).

The other experiment system to investigate the VOC removal performance of nonwovens cultivated carbon as an air filter is shown in Figure 1(b). The system is consisted of two chambers, ducts, a mechanical fan and an orifice flow meter. The nonwovens cultivated carbon with an equivalent circle of 10cm diameter was set on the outlet in the test chamber, and toluene was constantly emitted into the other chamber. The air was circulated by the fan and the contaminant was removed by the cultivated carbon filter. Two sampling points, before and after the filter, were set as shown in Figure 1(b). The *toluene* concentration of sampled air was analyzed according to the same time schedule as the static experiment.



(a) Passive experiment

(b) Active experiment

Figure 1. Experimental installations

The experimental conditions for the static experiment are shown in Table 1. In this study, BET specific surface 730 to 1240 g/m^2, different VOC gases such as *toluene, xylene* and *styrene*, and the low and high initial concentration levels, were investigated. The air temperature inside the chamber was controlled at 28 ^{o}C. Table 2 shows the experimental conditions for the active experiment to measure the removal efficiency, defined by the ratio of the difference between the VOC concentration in the chamber at the evaluated time and the initial concentration to the initial concentration, of nonwovens cultivated carbon used as an air filter. *Toluene* was used as a contaminant, and the initial concentration, air flow rate and surface velocity were 0.2 ppm, 0.282 L/s and 0.032 m/s, respectively.

Table 1. Conditions for passive experiment

Code	BET specific surface (m^2/g)	Air temperature (degree C)	Initial concentration (ppm)		
			Toluene	*Xylene*	*Styrene*
Blank (no sample)	NA	28 ± 0.5	0.07	0.2	0.05
			0.7	2.0	0.5
BET730	730		0.07	0.2	0.05
			0.7	2.0	0.5
BET820	820		0.07	0.2	0.05
			0.7	2.0	0.5
BET980	980		0.07	0.2	0.05
			0.7	2.0	0.5
BET1110	1,110		0.07	0.2	0.05
			0.7	2.0	0.5
BET1240	1,240		0.07	0.2	0.05
			0.7	2.0	0.5

Table 2. Conditions for active experiment

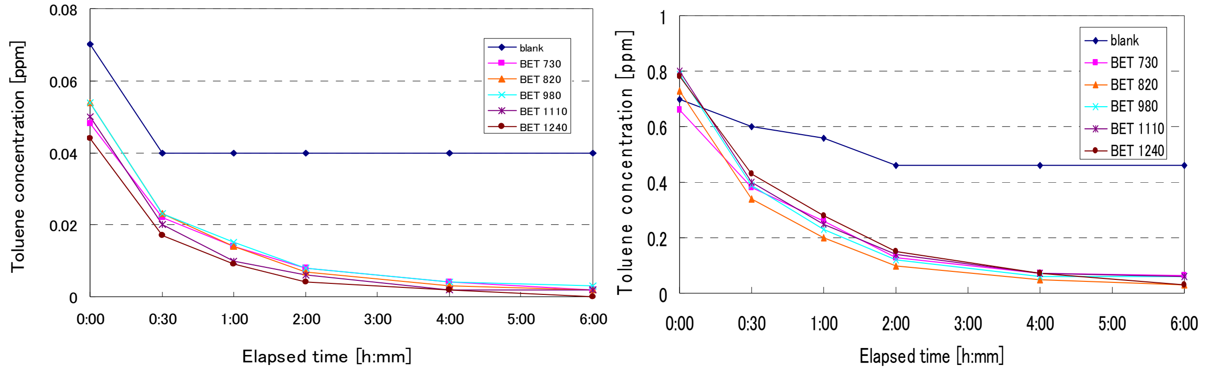
Code	Density (g/m^2)	BET specific surface (g/m^2)	Contaminant	Initial concentration (ppm)	Air flow rate (L/s)	Surface velocity (m/s)
BET730	164	730	*Toluene*	0.2	0.282	0.032
BET980	131	980				
BET1240	114	1,240				

3. RESULTS

3.1 Passive experiments

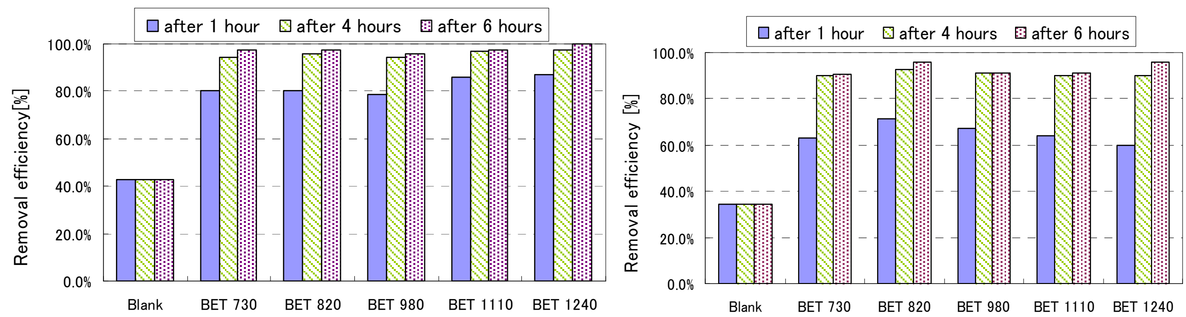
Two measurement results, *toluene* concentration change for the cases of the low and high initial concentrations, are shown in Figure 2. *Toluene* concentration in the small chamber without a test sample of nonwovens cultivated carbon sheet was about 0.4 ppm. The concentration decay speed for the low initial concentration was faster than that for the high initial concentration in the early time of the experiment. However the difference of concentration decay speed between the cases was almost same after 4 hours from the beginning time of the experiment. The difference of concentration decay among the sheets evaluated with different specific surface was small.

Figure 3 shows the removal efficiency evaluated for the different contaminants, *toluene, xylene* and *styrene*. Approximately 40 to 60% of the injected contaminant might be adsorbed on the inner surface of the chamber or the air inside the chamber was exchanged with the outside air. In general, the *toluene* removal efficiency for the low initial concentration was larger than that for the high initial concentration, especially in the early elapsed time from the beginning time. For the nonwovens cultivated carbon sheet with BET1240, the *toluene* removal efficiency was relatively high compared as the other contaminants such as *xylene* and *styrene* even in the early elapsed time. Also it can be found that the *styrene* removal efficiency for high initial concentration was relatively lower than any other cases investigated here.

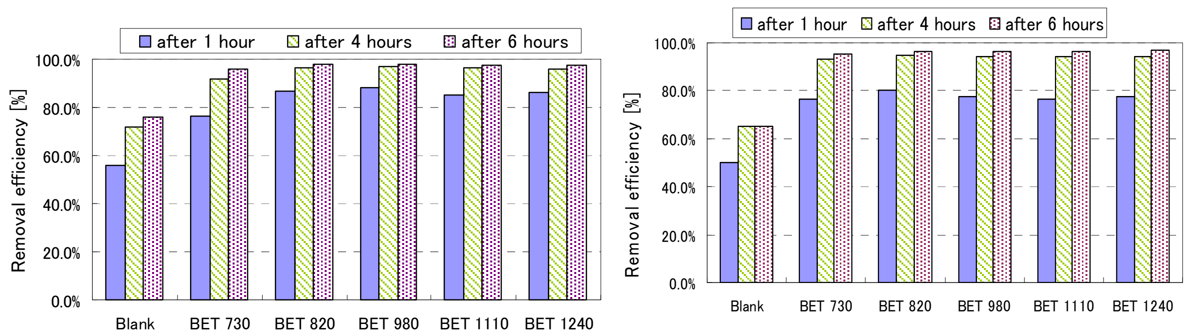


(a) Initial concentration (low) (b) Initial concentration (high)

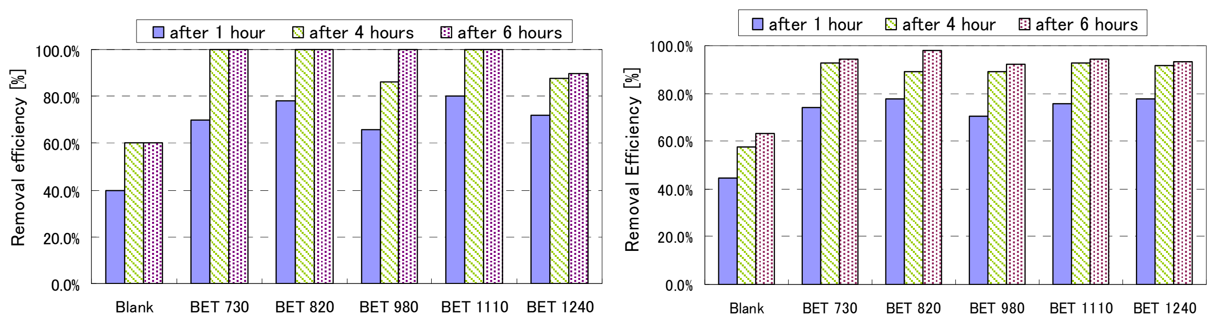
Figure 2. Concentration decay of *toluene* at different initial concentrations



(a) *Toluene* (low initial conc.) (d) *Toluene* (high initial conc.)



(b) *Xylene* (low initial conc.) (e) *Xylene* (high initial conc.)



(c) *Styrene* (low initial conc.) (f) *Styrene* (high initial conc.)

Figure 3. Removal efficiencies for different specific surfaces

3.2 Active experiments

Figure 4 shows *toluene* removal efficiency of nonwovens cultivated carbon filter with the different BET specific surfaces by the active experiment. The removal efficiencies for the different nonwovens activated carbon BET730 and BET1240 were almost constant regardless of the elapsed time from the beginning time of the active experiment. Moreover, it was found that the removal efficiency of BET1240 with large specific surface was smaller than that of BET730. It can be considered that the pore size of BET1240 is rather small to adsorb *toluene* compared with the other nonwovens activated carbon.

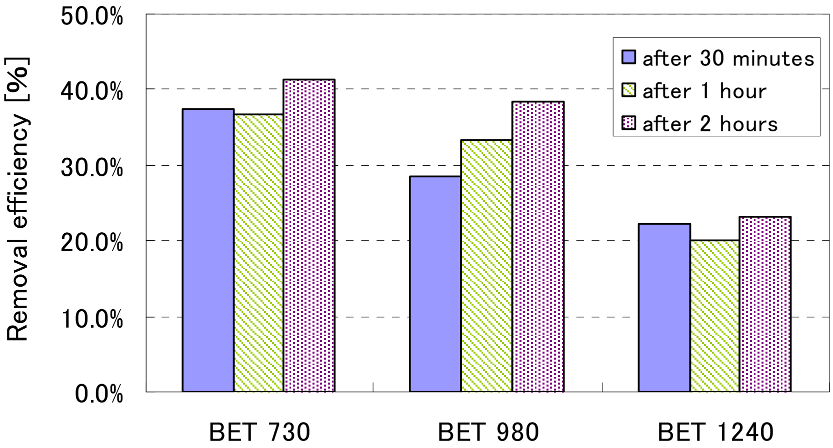


Figure 4. Toluene removal efficiency of nonwovens cultivated carbon filter with the different BET specific surface by active experiment

3.3 Temperature dependency of removal efficiency

Table 3 shows the VOC removal efficiency under different ambient temperatures for the passive experiment at the elapsed time, 1, 4 and 6 hours. The efficiency for *toluene, xylene* and *styrene* were measured. The removal efficiency at lower temperature 18 ^oC was slightly higher than that at higher temperature 28 and 38 ^oC. The temperature dependency of removal efficiency after 4 hours from the beginning of the experiment can be neglected at the ambient temperature, 18 to 38 ^oC.

Table 3. Removal efficiency and ambient temperature

Time / Temp.	*Toluene*			*Xylene*			*Styrene*		
	1 h	4 h	6 h	1 h	4 h	6 h	1 h	4 h	6 h
18 ^oC	84.3	95.7	100.0	81.0	93.0	95.5	62.0	100.0	100.0
28 ^oC	78.6	94.3	95.7	85.0	96.0	97.5	66.0	86.0	100.0
38 ^oC	77.1	94.3	96.4	70.0	93.0	95.0	60.0	84.0	100.0

4. CONCLUSIONS

The passive and active experiments of nonwovens cultivated carbon obtained from carbonizing and activating nonwovens made of fibrous waste to identify the VOC removal efficiency were done. As a result of experiments for nonwovens cultivated carbon sheets with different BET specific surfaces under the conditions, extremely high removal efficiencies for *toluene, xylene* and *styrene* were obtained. The removal performance under the static condition was relatively stable without regard to the specific surface. The temperature dependency of removal efficiency after 4 hours from the beginning of the experiment can be neglected at the ambient temperature, 18 to 38 ^oC. On the other hand, the removal efficiency of the nonwovens cultivated carbon used as a filter of air cleaner under the dynamic condition ranged from 20 to 40%, and the removal efficiency decreased as the specific surface increased. It can be concluded that nonwovens cultivated carbon has excellent performance to remove chemical contaminants and big potential to reduce environmental loads for sustainable society.

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