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Saturated Adsorption Amount of Chemical Compounds by Charcoal Board as Building Interior Materials

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Charcoal board was prepared by adhering charcoal powders with surperfine natural fibers as binder. The charcoal board retains characteristics of carbon adsorbability, deodorization property and humidity control. When the charcoal board is used for adsorbent as building interior materials, the environmental humidity in the indoor air changes depending on the seasons. It is, therefore, necessary to study influence of the humidity on the adsorption property of volatile organic compounds. Repetition property of the adsorption of formaldehyde gas and toluene gas was measured in the different relative humidity (RH); 31%, 53%, 81%. The saturated adsorption amount of formaldehyde increased slightly with increasing the RH, while in toluene adsorption, drastic decrease of the saturated amount was observed with increasing the RH. It was confirmed that the adsorbability by the charcoal board depends on the kind of chemical compounds and the RH in the environment.

Key words: charcoal board, adsorption, chemical compounds, relative humidity

1. INTRODUCTION

In Japan over 6 million tons of wasted construction biomass materials, 2 million tons of wasted paper and over 3 million tons of thinned wood in forest were burned and abandoned every year. Biomass waste re-evolves CO_2 by burning and decaying, while carbonization of biomass waste enables CO_2 to be fixed as charcoal which can be used as recycled resources. There is, however, the limitation in utilizing charcoal, because demands of the charcoal as fuel and soil remover are not so large in the market.

Recently, indoor air pollution with some volatile organic compounds (VOCs) generated from new building interior materials, plywood, wall paper, insecticides, etc. is a problem in a newly constructed housing: Sick Building Syndrome or Chemical Sensitivity. It is well known that charcoal has been used as odor adsorption agent. Carbonization temperature dependence on gas adsorption property of charcoal was reported [1][2]. We have proposed charcoal board, new material which is conscious of our environment [3]-[5]. It is expected that charcoal board can be effective to calm the problem by adsorbing VOCs in indoor air. We applied, therefore, the charcoal board to the building interior materials of the room model [6]. As the charcoal board is used as interior material in rooms in real life, environmental humidity changes dependently upon the seasons and the conditioned air. It was found that relative humidity (RH) affected the adsorbability of chemical compounds [7][8]. In this paper, comparison of adsorption test in different humidity condition was repeated to estimate influence of environmental humidity on the adsorption property of toluene ($C_6H_5CH_3$), formaldehyde (HCHO) and ammonia (NH_3), by the charcoal board.

2. EXPERIMENTAL

2.1 Sample Preparation

Preparation method of the charcoal board is as follows: Charcoal board was produced by binding charcoal powder with superfine natural fibers as adhesive. The charcoal powder was made from biomass waste. The superfine cellulose and collagen fibers were prepared from defiberized milk cartons and leather scrap with a grinder, respectively. The diameter of the superfine natural fibers was obtained about 100 nm. The charcoal board with specific gravity of about 0.4 is shown in Fig. 1.

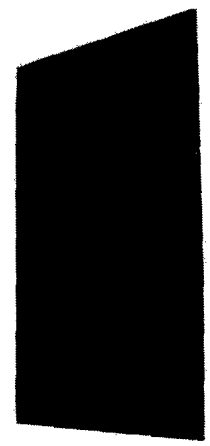

Fig. 1. Photograph of charcoal board. 910 mm×455 mm×10~20 mm

Table 1. Defined environmental RH for adsorption test for building materials [9], environmental RH for adsorption experiment and sample preparation condition.

	Low RH	Middle RH	High RH
Defined RH [9]	13-31%	34-74%	75-98%
RH for experiments	31%	53%	81%
Sample preparation condition	Dried at 105°C for 24 hours	Placed in 53% for two weeks	Placed in 93% for two weeks

One of the characteristics of the charcoal board is to use industrial waste as raw materials. And charcoal board does not contain harmful compounds and does not generate them in the production process either.

2.2 Adsorption test

Size of the test sample was 30 mm x 30 mm and 2 mm in thickness, which was dried at 105°C for 12 hours. The sample surface except the front surface (30 mm x 30 mm) was covered by aluminum tape in order to prevent adsorption of gas from the back surface and the side surface. The Tedlarbag was used for a adsorption test chamber. Detector tube was used for measurement of chemical compound concentration in the chamber. Toluene, formaldehyde and ammonia were selected as adsorbate gas. Initial concentration of the gas was adjusted to 100 ppm in the chamber. The adsorption property was measured at 23°C.

Table 1 shows defined environmental (RH) for testing adsorption/desorption efficiency for building materials by the Japan Testing Center for Construction Materials [9], environmental RH for adsorption experiment in this study, and sample preparation condition. In this experiment, about 31%, 53%, and 81% of RH were adopted as the low, middle and high humidity, respectively. Preparation condition of the samples as follows: The samples were dried at 105°C for 24 hou before the test. Before the adsorption test, moisture content of the charcoal board was pre-equilibrated by placing the board in the respective RH for two weeks; the samples were allowed to stand in RH 53% and 93% before the middle RH test and the high RH test, respectively. Fig. 2 shows relationship between environmental RH and equilibrium moisture content of the charcoal board. The moisture content depends on the RH. The equilibrium moisture content of 12.5% and 15% was obtained in the sample placed in the middle RH and high RH environment.

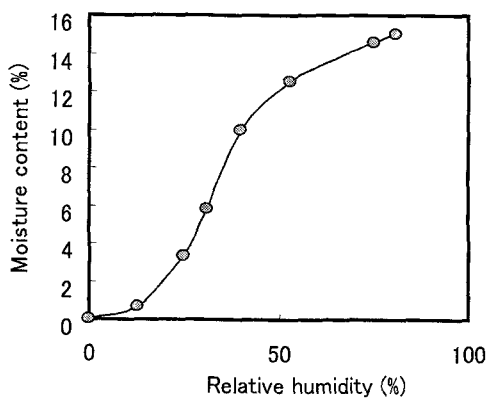

Fig. 2 Relationship between RH and equilibrium moisture content of the charcoal board.

3. RESULTS AND DISCUSSION

As charcoal has porous structure, chemical compounds can be adsorbed into the pore surface. Fig. 3 shows time dependence of adsorption of toluene by the charcoal board in the low RH condition. In the first run the charcoal board adsorbs toluene from 100 ppm to 30 ppm for 300 minutes. In the twenty fourth run, the board adsorbs toluene from 100 ppm to 60 ppm. This result means that, when the adsorption test run was repeated, the adsorption amount per one test run gradually decreases.

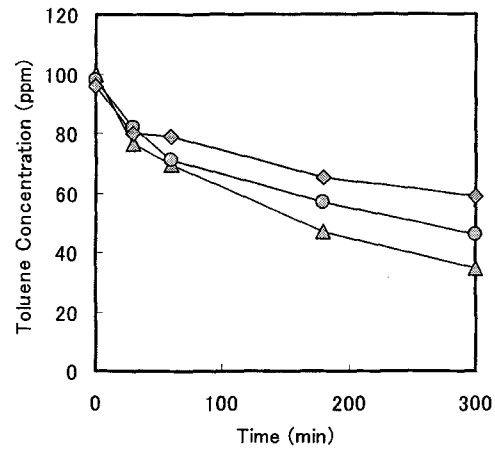

Fig. 3 Time dependence of adsorption of toluene by the charcoal board in low RH condition. ▲; the first run, ●; the tenth run and ◆; the twenty forth run

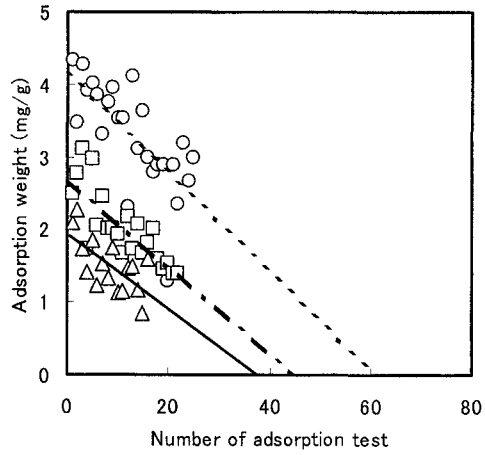

Fig. 4 Reduction of toluene adsorption weight in repetition of adsorption test run by the charcoal board. ○; low humidity, □; middle humidity and △; high humidity.

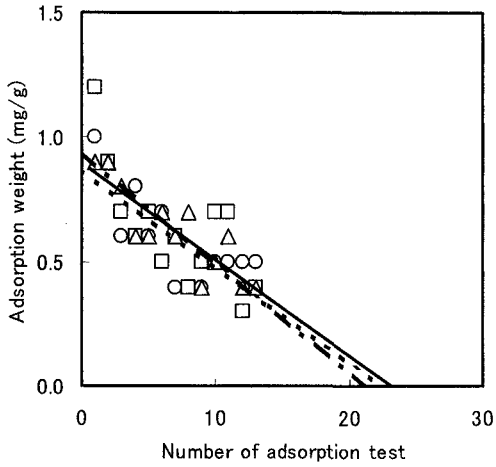

Fig. 5 Reduction of formaldehyde adsorption weight in repetition of adsorption test run by the charcoal board. ○; low humidity □; middle humidity and △; high humidity.

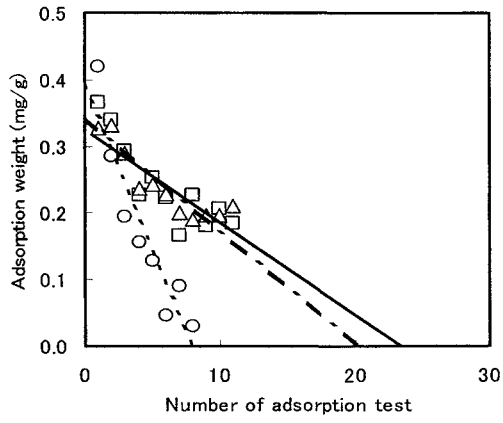

Fig. 6 Reduction of ammonia adsorption weight in repetition of adsorption test run by the charcoal board. ○; low humidity, □; middle humidity and △; high humidity.

It was observed that, when the adsorption test run was repeated, finally the charcoal board adsorbed no gas any more. Then saturated adsorption amount of gas in the charcoal board was estimated by integrating of the adsorption amount in repetition of the adsorption test run.

The adsorption test run was carried out under different humidity condition. Fig. 4 shows reduction of toluene adsorption weight in repetition of the adsorption test run in the low, middle and high RH condition. The lines in the figure were calculated with the least square method. In the low humidity, the first adsorption weight is 4 mg/g and the value is twice of the one in the high humidity. The adsorption saturated times in the low humidity is estimated as 60 runs.

Reduction of formaldehyde adsorption weight in repetition of the adsorption test run in different RH conditions is shown in Fig. 5. Influence of the environmental RH on the formaldehyde adsorption property is not observed. The adsorption saturated times is estimated as 20 runs.

Fig. 6 shows reduction of ammonia adsorption weight in repetition of ammonia adsorption by the charcoal board in the low, middle and high RH condition. It was confirmed in the high and middle RH that saturated ammonia adsorption weight is larger than that in the low RH. The saturated adsorption amount was estimated to 1.3 mg/g in the low RH, 3.7 mg/g in the middle RH and 3.9 mg/g in the high RH. From these results, it is suggested that adsorption sites were increased by swelling in the high humidity, and therefore, the saturated adsorption amount of the charcoal board increased.

Saturated adsorption amount of toluene, formaldehyde and ammonia by the charcoal board, which was calculated by integration of adsorption weight, is shown in Fig. 7. Saturated adsorption amount of toluene decreases with increase of RH, while ammonia adsorption increases with increase of RH. It is observed that environmental humidity does not influence the saturated adsorption amount of formaldehyde.

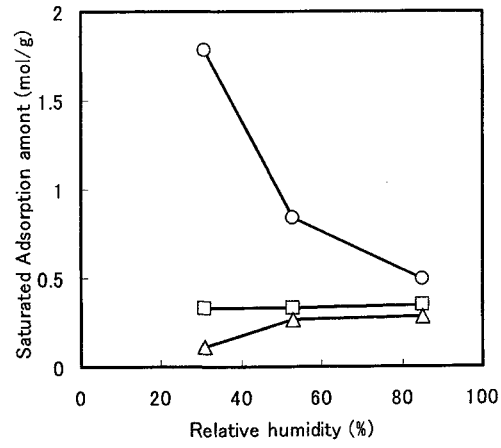

Fig. 7 Saturated adsorption amount of chemical compounds by the charcoal board. ○; formaldehyde, □; toluene and △; ammonia.

4. CONCLUSIONS

Influence of the environmental humidity on the adsorption property of chemical compounds by the charcoal board was studied. Repetition property of the adsorption of toluene, formaldehyde and ammonia gas was measured in different RH conditions; 31%, 53% and 81%. In toluene adsorption the saturated amount decreased with increasing RH, while the saturated adsorption amount of ammonia increased slightly with increasing RH. It is observed that environmental humidity does not influence the saturated adsorption amount of formaldehyde.

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