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Properties of Water-Based Paint Mixed with Adsorbent

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Abstract.

BACKGROUND/OBJECTIVES: According to COVICD-19, the spread of non-face-to-face culture leads to an increase in the amount of time spent indoors, and measures against indoor air pollutants are needed.

METHODS/STATISTICAL ANALYSIS: In order to reduce the concentration of VOCs, HCHO, and fine dust (PM 2.5), powder activated carbon is used among the adsorbents, mixed with water-based paints, and the impact resistance, alkali resistance, and adsorption performance of the paint are examined. As experimental conditions, the coating thickness is 0.1mm, and the addition ratio of powdered activated carbon is selected as 0, 5, 10, 15, 20 (%).

FINDINGS: In the indoor air pollutant adsorption experiment, the concentration of VOCs, HCHO and fine dust (PM 2.5) decreased as the addition ratio of powdered activated carbon increased. It is believed that indoor air pollutants are adsorbed on the surface of powdered activated carbon and moved from the surface to pores and micropores by capillary condensation, and physically adsorbed to the inner pores. Alkali resistance was more pronounced in the part immersed in the calcium hydroxide solution when powdered activated carbon was added compared to when powdered activated carbon was not added. It is believed that this is because the paint mixed with powdered activated carbon has a lower pH than that of the calcium hydroxide solution. The impact resistance was clearly discolored when powdered activated carbon was added compared to when powdered activated carbon was not added, and there was no difference in the degree of cracking, discoloration, and depression.

IMPROVEMENTS/APPLICATIONS: If an appropriate addition ratio of powdered activated carbon is derived and used, it is judged that it can be used as a functional paint and improving indoor air quality.

Keywords: Adsorbent, Powdered activated carbon, Water-based paint, VOCs, HCHO, Fine dust (PM 2.5)

1. INTRODUCTION

COVID-19, which hit the world in 2020, is fundamentally changing the lifestyle of mankind. The biggest change is the spread of non-face-to-face culture.[1] The spread of non-face-to-face culture inevitably leads to an increase in the time spent indoors, and measures against indoor air pollutants are required as shown in [Figure 1].[2,3] As shown in [Figure 2], indoor air pollutants are released by concrete on the inner wall, paints and construction materials, which are finishing materials.[4] If you inhale a large amount of these indoor air pollutants, symptoms of headache, vomiting and dizziness appear.[5] Therefore, this study aims to prepare functional paints using adsorbents and examine the adsorption performance and functionality of volatile organic compounds (VOCs), formaldehyde (HCHO) and fine dust (PM 2.5).

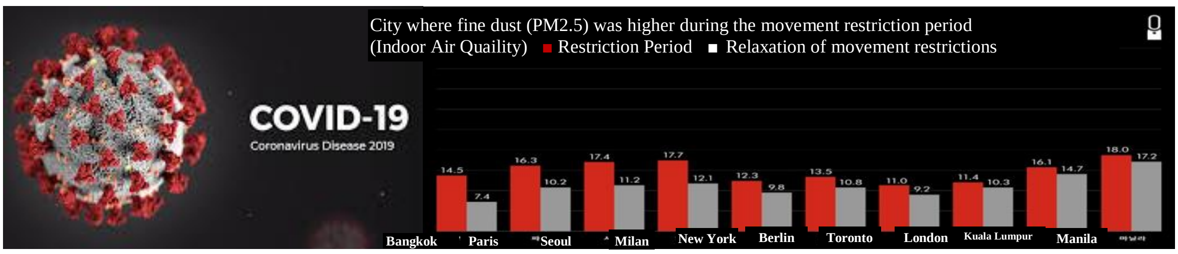

Figure 1. Covid-19 and The number of fine dust in each city according to the time of restriction (source : https://www.ngenebio.com / https://www.hellot.net)

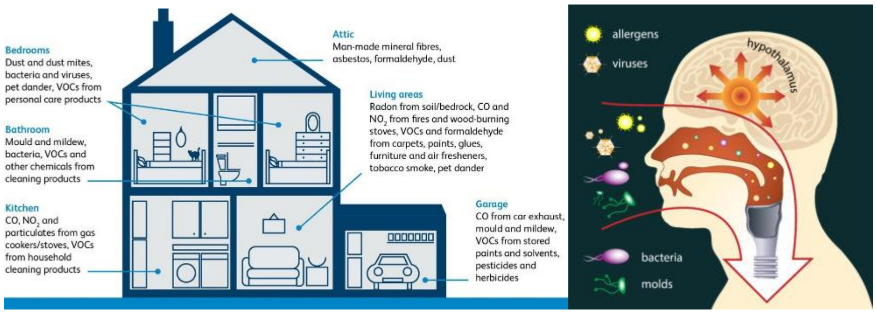

Figure 2. Indoor air pollution source and type
(source : https://www.medium.com / https://www.indoordoctor.com)

2. EXPERIMENTAL PLAN

In order to reduce the concentration of VOCs, HCHO and fine dust (PM 2.5), this experiment is to mix with water-based paint using powdered activated carbon among the types of adsorbents, and examine the functionality and adsorption performance of the paint. As for the experimental level, as shown in [Table 1] below, water-based paint is used as the paint, and the painted surface type is cement paste. In addition, the addition ratio of powdered activated carbon is 0, 5, 10, 15, 20 (%), and the coating thickness is 0.1 mm. Finally, the curing conditions are dry curing (18℃), and the experimental items are selected as VOCs concentration, HCHO concentration, fine dust (PM 2.5) concentration, alkali resistance and impact resistance.

Table 1. Experimental factors and levels

Experimental factors	Experimental levels	
Paint type	Water-based paint	1
Painted surface type	Cement paste	1
Addition ratio of PAC[1)]	0, 5, 10, 15, 20(%)	5
Coating thickness	0.1 (mm)	1
Curing conditions	Dry curing (18℃)	1
Experimental items	VOCs concentration, HCHO concentration, Fine dust (PM 2.5) concentration, Alkali resistance, Impact resistance	5

1) PAC : Powdered Activated Carbon

2.1. MATERIALS

2.1.1. POWDERED ACTIVATED CARBON (PAC)

Activated carbon is a material with excellent adsorption performance as an aggregate of amorphous carbon produced by activating with water vapor at a high temperature of 900 to 1200°C as raw materials of plant-based sawdust, wood and coconut shells and mineral-based coals.[6] In the activation process, many micropores are formed, and the adsorbed material is adsorbed by applying attractive force to the surrounding liquid or gas.[6,7] Powdered activated carbon used in this study is shown in [Figure 3]. In terms of physical properties, the specific surface area is 1,135m^2/g, the density is 0.43g/cm^3, and the chemical components are shown in [Table 2].[8,9]

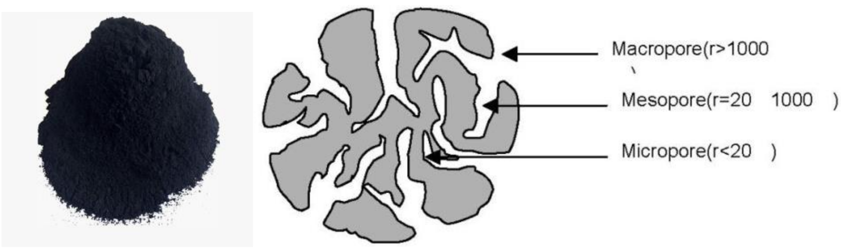

Figure 3. Powdered activated carbon (PAC) and pore structure
(source : **http://jscarbon.net** / **https://m.blog.naver.com/jmsin30/220821276499**)

Table 2. Chemical composition of powdered activated carbon

Chemical composition					
CaO	**Fe_2O_3**	**SiO_2**	**SO_3**	**Al_2O_3**	**MgO**
19.20	17.80	11.50	7.75	2.96	2.24

2.1.2. WATER-BASED PAINT

Paint hardens when applied to the surface of an object to form a film and prevent corrosion of the surface. It is also a generic term for a fluid substance that gives luster and color.[10] The water-based paint used in this study was an acrylic emulsion paint for stone coat (AP-99) manufactured by Korean Company A, and its physical properties are as shown in [Table 3]. In addition, it has excellent water resistance and weather resistance, so it has excellent gloss when applied to the surface.[5]

Table 3. Physical properties of water-based paint (AP-99)

Physical properties				
Solid content (%)	**pH**	**Viscosity (cPs)**	**Density (g/cm^3)**	**Color**
45±1	8.5 ~ 9.5	500-2,000	1.04(at 25℃)	Slightly transparent white

2.2. EXPERIMENTAL METHODS

2.2.1. VOCS AND HCHO ADSORPTION TEST

VOCs and HCHO adsorption test methods are proposed by Hanbat National University and are shown in [Figure 4]. First, a substance that causes VOCs and HCHO components is put in an empty chamber and measured using a measuring instrument until the concentration of VOCs and HCHO in the empty chamber is constant. Second, if the concentrations of VOCs and HCHO were kept constant, open the cover of the empty chamber, put the test sample of 160x160x40 (mm^3), and measure the VOCs and HCHO concentrations.

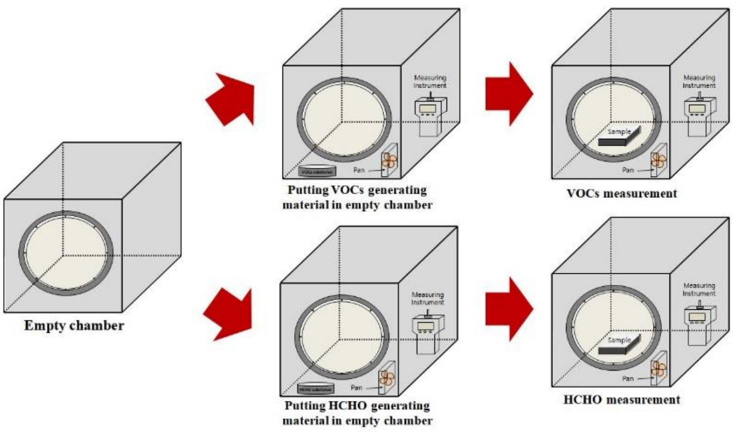

Figure 4. VOCs and HCHO measurement method

2.2.2. FINE DUST (PM 2.5) ADSORPTION TEST

The method for the adsorption test of fine dust (PM 2.5) is as shown in [Figure 5]. First, the fine dust is injected into the empty chamber for 1 hour using a fine dust generator. Second, after 1 hour, the injection of fine dust is stopped, the cover of the empty chamber is opened, and a test sample of 160x160x40 (mm3) is placed, and the concentration of fine dust (PM 2.5) is measured.

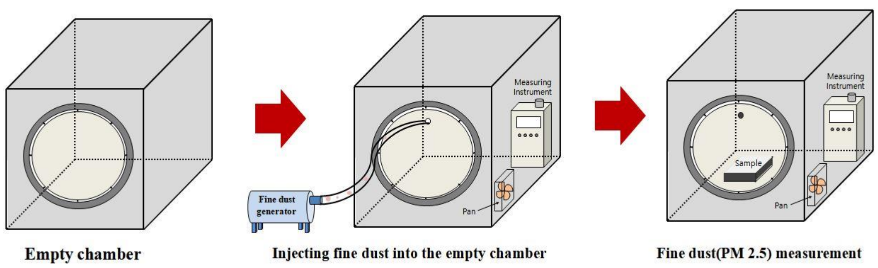

Figure 5. Fine dust (PM 2.5) measurement method

2.2.3. ALKALI RESISTANCE TEST

The alkali resistance is measured based on KS F 4715(thin finishing wall coating material). First, a functional paint mixed with powdered activated carbon is coated on a 150x50x30 (mm3) test sample. Second, paint the back and sides using epoxy resin paint. Third, fill the beaker with a calcium hydroxide solution (20±2℃) to a height of about 90mm. Then, the test sample is soaked vertically for about 24 hours. Finally, take out the test sample and wipe the surface. Then, after drying in the air-dry condition for 3 hours, visually check the presence or absence of fine cracking, deformation, swelling, peeling, and melting, and measure by comparing with the part not immersed in the test solution.

2.2.4. IMPACT RESISTANCE TEST

The test sample to be used for measuring the impact resistance is made of 300x300x60 (mm3) based on KS F 2221(Impact test method for building boards), and a functional paint mixed with powdered activated carbon is coated on the test sample. Impact resistance is measured based on KS F 4715(thin finishing wall coating material). First, measure by dropping a weight of 500g from a height of 300mm based on the upper surface of the test sample. Second, it is carried out in three places per test sample, and the distance between hitting points is 50mm or more. Finally, visually check whether there is fine cracking, swelling, deformation, or peeling.

3. EXPERIMENTAL RESULT AND ANALYSIS

3.1. VOCS CONCENTRATION

[Figure 6] below shows the reduction rate of VOCs concentration according to the addition ratio of powdered activated carbon. When the standard concentration of VOCs (130PPM) is set as 100% and the addition ratio of powdered activated carbon is 0, 5, 10, 15, 20 (%), the reduction rate of VOCs concentration is 100, 76.0, 71.9, 69.0, 62.8 (%). Therefore, as the addition ratio of powdered activated carbon increased, the concentration of VOCs tended to decrease. Adsorption has physical adsorption and chemical adsorption, and the adsorption amount increases when the temperature is low. In addition, physical adsorption occurs due to physical attraction between gas molecules and the solid surface at low temperatures, and chemical adsorption occurs at high temperatures. Therefore, since the environment of the chamber used in this study is low temperature (20±3℃), it can be considered as physical adsorption. Finally, it is judged that powdered activated carbon is an adsorbent having a porous structure, and the concentration of VOCs is reduced by adsorbing VOCs by the fine pores present inside.

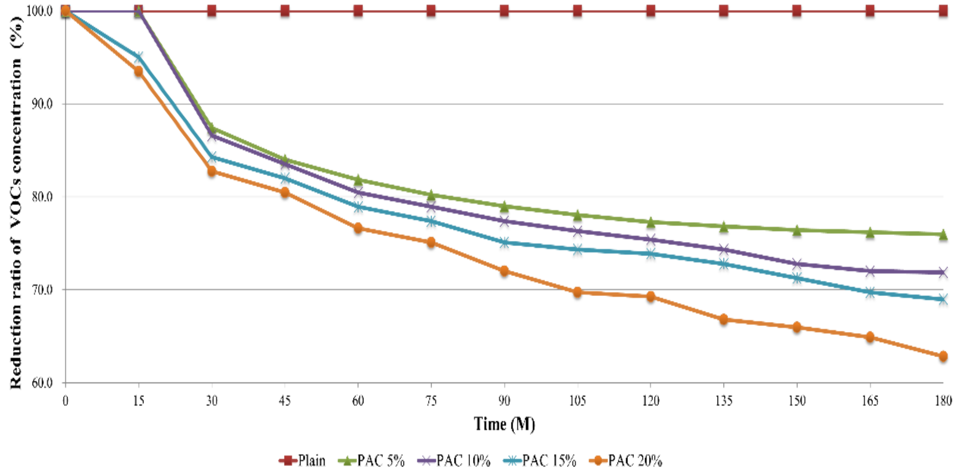

Figure 6. VOCs concentration reduction rate according to the addition ratio of PAC

3.2. HCHO CONCENTRATION

[Figure 7] below shows the reduction rate of HCHO concentration according to the addition ratio of powdered activated carbon. When the HCHO standard concentration (18.15PPM) is set as 100% and the addition ratio of powdered activated carbon is 0, 5, 10, 15, 20 (%), the HCHO concentration reduction rate is 100, 44.6, 33.6, 30.3, 26.3 (%). Therefore, as the addition ratio of powdered activated carbon increased, the HCHO concentration tended to decrease. For the same reason as the VOCs concentration reduction rate, the environment of the chamber is at a low temperature (20±3°C). In addition, it is considered that the concentration of HCHO decreased by adsorbing the surrounding gas (HCHO) into the micropores by the attractive force of the functional groups of carbon atoms present on the inner surface of powdered activated carbon.

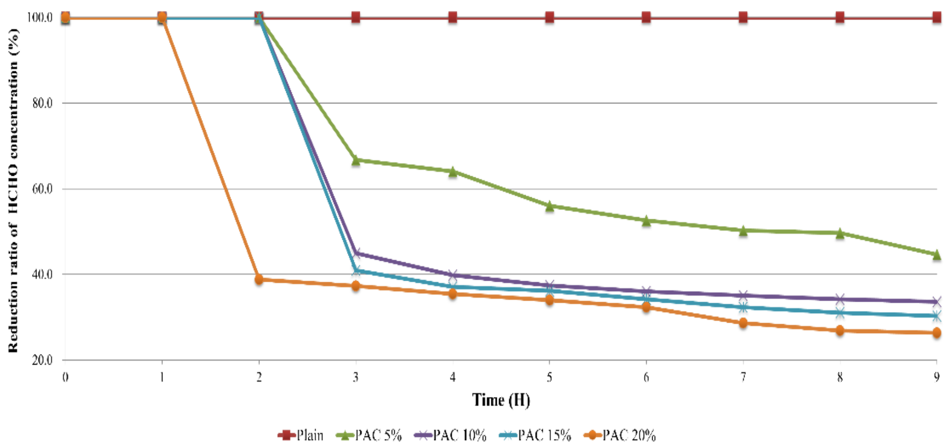

Figure 7. HCHO concentration reduction rate according to the addition ratio of PAC

3.3. FINE DUST (PM 2.5) CONCENTRATION

[Figure 8] below shows the reduction rate of fine dust (PM 2.5) concentration according to the addition ratio of powdered activated carbon. When the standard concentration of PM 2.5 (71.8 ㎍/m^3) is set as 100% and the addition ratio of powdered activated carbon is 0, 5, 10, 15, 20 (%), the reduction rate of fine dust (PM 2.5) concentration is 46.0, 26.5, 18.5, 5.3, 0.5 (%). Therefore, as the addition ratio of powdered activated carbon increased, the concentration of fine dust (PM 2.5) tended to decrease. Fine dust is a mixture of solid and liquid air. Finally, it is thought that fine dust (PM 2.5) was adsorbed on the surface of powdered activated carbon, moved to pores and micropores by capillary condensation, and adsorbed to the inner pores.

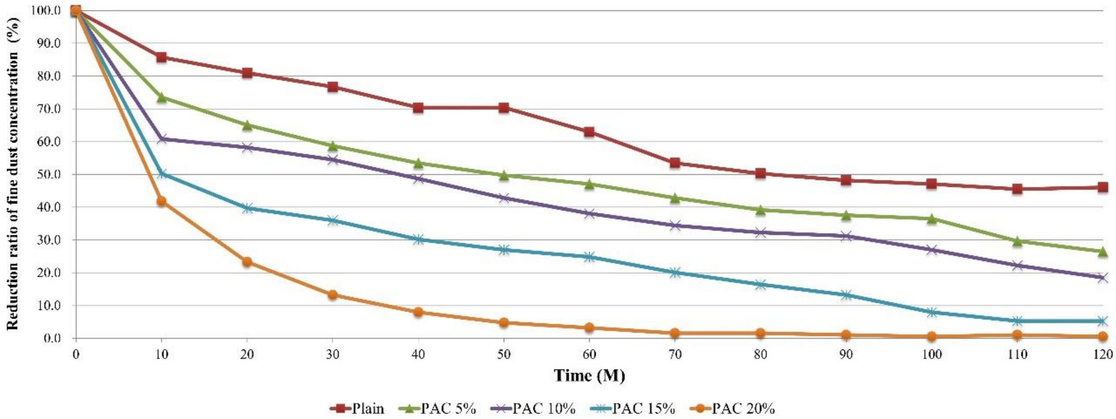

Figure 8. Fine dust (PM 2.5) concentration reduction rate according to the addition ratio of PAC

3.4. ALKALI RESISTANCE

[Figure 9] shows the alkali resistance according to the addition ratio of powdered activated carbon. Based on the red line in [Figure 9], the left side is the part immersed in calcium hydroxide solution and the right side is the part not soaked. As a result of the experiment, the left side of the case without the addition of powdered activated carbon showed a color change from transparent color to white overall around the red line compared to the right side, and it was judged that the performance was degraded. In addition, when powdered activated carbon was added, fine cracking, deformation, swelling, peeling and melting were not seen on the left side compared to the right side, and the soaked part was clearly discolored to white. This is believed to be due to the lower pH of the paint mixed with powdered activated carbon compared to the calcium hydroxide solution.

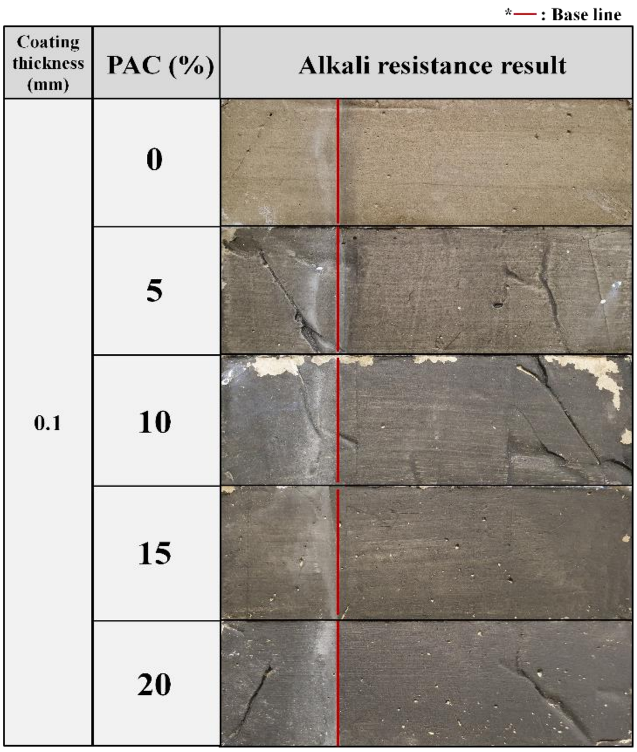

Figure 9. Alkali resistance according to the addition ratio of PAC

3.5. IMPACT RESISTANCE

[Figure 10] shows the impact resistance according to the addition ratio of powdered activated carbon. As a result of the experiment, when powder activated carbon was not added, there was no evidence of fine cracking, severe deformation, and peeling from the base plate except that the striking part was dent. When the addition ratio of powdered activated carbon is 5, 10, 15, and 20 (%), compared to the case where powdered activated carbon was not added, the degree of depression in the hitting part was judged to be similar. In addition, when powdered activated carbon was added from 10%, discoloration appeared at the same time as the dent in the hitting part.

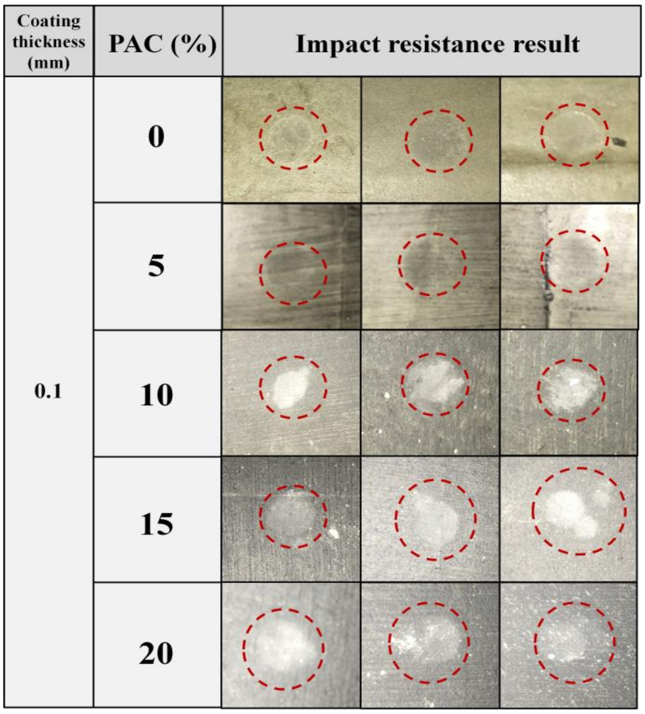

Figure 10. Impact resistance according to the addition ratio of PAC

4. CONCLUSION

As the time to stay indoors increases due to COVID-19, countermeasures against indoor air pollutants are needed. Therefore, this study examined the adsorption performance and functionality of VOCs, HCHO and fine dust (PM 2.5) using powdered activated carbon as an adsorbent to remove indoor air pollutants. As a result, the concentration of VOCs, HCHO, and fine dust (PM 2.5) decreased as the addition ratio of powdered activated carbon increased. In addition, the alkali resistance, which is the functionality of the paint, has a distinct color change when powder activated carbon is added compared to when powder activated carbon is not added, and there is no difference depending on the addition ratio of powdered activated carbon. In impact resistance, discoloration was more pronounced when powdered activated carbon was added than when powdered activated carbon was not added, and there was no difference in the degree of depression. Finally, if an appropriate addition ratio of powdered activated carbon is derived and used, it is judged that it can be used as an actual functional paint and improve indoor air quality.

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