Mock-up Test for NOx Reduction by Photocatalyst Paint for Indoor Use

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Abstract. In this study, the photocatalyst TiO₂ was mixed with a general paint and applied on indoor walls as part of a mock-up test to measure the reduction in the NOx concentration affected by the on or off state of a UV lamp. The findings may be summarized as follows; the NOx concentration was reduced by approximately 7% more (0.134 ppm) with the UV lamp on than when the lamp was off in the indoor space where the paint mixed with TiO₂ was applied.

1 Introduction

In recent years, particulate matter (PM10) have received much public attention due to their effects on health. Particularly, in Korea, the level of particulate matter is relatively higher than that in other major OECD countries. With many people currently spending more than 90% of their time indoors, particulate matter have ultimately become a health threat to indoor residents. To explore one of the methods of reducing particulate matter, a mock-up test was conducted in this study, to examine the performance of TiO₂–mixed paint for indoor use in reducing NOx, one of the main precursors to particulate matter. This study will prove its usefulness, as a basic study on the reduction of particulate matter, in the future.

2 Properties of Photocatalysts

2.1. Material Properties of Photocatalysts

A photocatalyst is a material that generates a certain reaction in response to light, enabling a chemical reaction induced only by light. In general, photocatalysts are used in semiconductors. Some of the most well-known photocatalysts include zinc oxide, cadmium oxide, tungsten oxide, and titanium oxide. The classification in accordance with the material properties of photocatalysts is shown in Table 1 below:

Table 1. Classification physical property of photocatalyst

| Representative properties | Contents |
|---------------------------|---------|
| Crystallization type       | Rutile, Anatase, and Brookite exist, and Rutile is the most stable |
| Stability                 | Very stable material that does not dissolve in acid, alkalai, water, and organic solvents under normal temperature and pressure conditions |
| Representative application| Generally used in toothpaste and cosmetics |

2.2. Characteristics of TiO₂ as Photocatalyst

Of the four types, the photocatalyst that is used most widely is TiO₂, due to its air-purifying, antibacterial, deodorizing, and other such features. Specifically, the photocatalyst may be utilized as shown in Table 2:

Table 2. Characteristics of titanium dioxide photocatalyst

| Characteristic | Contents | Representative utilization |
|----------------|---------|----------------------------|
| Antifouling    | Degradation and removal of pollutants by superhydrophilic action | Automotive coating |
| Air Cleaning   | Removal of nitrogen oxides and sulfur oxides in air | Air-purification artificial plants, Building wall coating |
| Antibacterial  | Oxidation of organics by OH radicals | Air-conditioner filter |
| Deodorization  | Removal of VOCs and odors | Clothes-deodorizing device |
| Water Purification | Wastewater treatment | Factory wastewater and sewage treatment facility |

Air purification of TiO² photocatalysts is done through oxidation reactions, and oxidation reactions to NOx used in this experiment are shown in Table 3.

Table 3. Photocatalytic oxidation mechanism of nitrogen oxides

| Activation | TiO₂ + hv* → h⁺ + e⁻ |
|------------|----------------------|
| Absorption | H₂O(g)+Site*→H₂O_ads+O(g)+Site*→O_2ads+NO(g)+Site*→NO_2ads+NO_2ads+Site*→NO_2ads |
| Hole trapping | H₂O+h⁺→·OH+H⁺ |
| Electron trapping | O₂+e⁻→O_2⁻ |
| Hydroxyl attack | NO_2ads⁺·OH→NO_2ads+H₂O |
| Superoxide attack | NO+O_2→NO_2⁻ |

* hv : (UV), **Site : Surface of TiO₂

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3 Mock-Up Test

3.1. Introduction

For the purpose of the study, TiO$_2$ – known for its air-purifying property – was mixed with a general paint and applied on the walls inside a mock-up test room ($2,675 \times 2,750 \times 2,860$). To confirm the air-purifying effects of TiO$_2$, a UV lamp was used, since light energy is not as readily available in indoor spaces as in outdoor spaces. After the TiO$_2$-mixed paint was applied on the walls, NOx, one of the major precursors to particulate matter, was injected, in the form of a gas, into the room until a certain level of concentration (2 ppm) was attained. Thereafter, the changes in the concentration were measured with the UV lamp turned on and off. The indoor temperature was set at 25 $^\circ$C. The details are shown in Fig. 1 and Table 3.

![Mock-Up Test Plan & 3D Picture](image)

**Fig. 1.** Mock-Up Test Plan & 3D Picture

| Classification       | Contents                                   |
|----------------------|--------------------------------------------|
| Test Gas             | NO gas                                     |
| UV Lamp              | UV-A BLB lamp, 0.505 mW/cm$^2$             |
| Number of Experiments| UV ON-OFF 3 times, total 6 times           |
| Measurement Interval | 1 min                                      |
| Measurement Instrument| Chemiluminescence instrument               |
| Measurement Time     | 3 hours after attaining 2 ppm concentration |

**Table 3. Mock-Up Test Summary**

3.2. Mock-Up Test Result

Considering the margin of error, three tests were conducted to use the average value. Fig. 2 shows the NOx concentration rising to 2 ppm after the precursor was introduced into the closed mock-up test room painted with TiO$_2$-mixed paint.

![NOx Concentration Rise Graph](image)

**Fig. 2.** NOx Concentration Rise Graph

When the NOX concentration reached 2 ppm in the closed room painted with TiO$_2$-mixed paint, the introduction of NOx was stopped. Fig. 3 and Table 4 show the reduction in the NOx concentration three hours after turning the UV lamp on/off. The values indicated on the graph are the averages taken from three tests, each conducted with the UV lamp on/off.

![NOx Concentration According to Status of UV Lamp](image)

**Fig. 3.** NOx Concentration According to Status of UV Lamp

It was found that in the closed room where TiO$_2$-mixed paint was applied on the walls, the NOx concentration was approximately 7% (0.134 ppm) lower with the UV lamp on than with the lamp off.

4 Conclusions

The findings of this study can be summarized as follows; In the mock-up test on an internal space where TiO$_2$ with air-purifying property was mixed with a general paint and painted on the wall, the reduction in the NOx concentration was measured to compare the on and off states of a UV lamp. It was found that in the indoor space where TiO$_2$-mixed paint was used, the NOx concentration was approximately 7% (0.134 ppm) lower with the UV lamp on than with the lamp off.

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