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Application of $Linbo_3$ Photocatalyst in Concrete as Environmental Friendly Solution for Indoor Air Purification

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ABSTRACT

The addition of a photocatalyst to ordinary building materials such as concrete creates environmental friendly materials by which air pollution or pollution of the surface itself can be diminished. The use of LiNbO3 photocatalyst in concrete material would be beneficial since it reduces VOC from indoor environment. In the present study, a concrete block with LiNbO3 coating was used to remove a VOC toluene from indoor air. The effectiveness of LiNbO3 coating concrete block was investigated to remove toluene under various operational parameters. The percentage of pollutant removal increased with increasing irradiation time. A higher depth coating resulted in a better removal rate and the maximum depth of coatings that can be applied was 0.75mm. Due to the ease of usage and good photocatalytic efficiency, the research work done showed its potential application in pollution prevention.

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INTRODUCTION

People generally spend more than 80% of their time in indoor environment (Juan, 2003). The quality of indoor air has a direct impact on human health in terms of lengthened exposure to pollutants by inhalation. Toluene is one of the major pollutants in indoor environments come from varieties of sources like adhesives, building materials, consumer commercial products and Furnishings and clothing (Hoffmann, 2008). These compounds are widely used in indoor environment because they exhibit the desirable characteristics of good insulation properties, economy, fire resistance, and case of installation (Chapuis, 2002). The concentration of Toluene usually found in this environment ranged from 10 ppb to 100 ppb (Nath, 2012).

For improving indoor air quality, the application on pavement surfaces or on the building surfaces in cementitious materials gives optimal solutions (Ao, 2005). To increase the efficiency of the photocatalyst, its presence at the surface of the material is crucial (Ching, 2004). Consequently, the pollutant has to be absorbed on the surface and oxidized or reduced to a less harmful element.

Most of the efforts have been devoted to the study of photocatalytic processes using semiconductor oxides, such as $LiNbO_3$, TiO_2, CdS or ZnO because of their efficiency in the degradation of volatile organic compounds (VOCs) (Ibram Ganesh, 2011; Stock, 2011). Till now, the majority of the work in this area has involved TiO_2 in construction purpose. This material has a band gap energy of 3.2eV and therefore it absorbs light energy which is close to ultraviolet range (~380nm). In 2011, Matt Stock and Steve Dunn (Stock, 2011) found that $LiNbO_3$ could be produced more products under UV and visible irradiation than TiO_2 despite its wider band gap (3.78eV). The high yield product using $LiNbO_3$ is explained by its strong remnant polarization ($70\mu c/cm^2$), which is not found in TiO_2 (Nath, 2013). The goal is to have as much $LiNbO_3$ as possible at the surface of the material, without the risk of losing it by abrasion or weathering (Stock, 2011). The use of white cement with $LiNbO_3$ at the surface of buildings and construction attribute to the durability of the visual aspect of the building (Peter, 1996). Due to the photocatalytic action, the whiteness of th e building will remain and dirt will be washed away more easily due to the hydrophilic properties or will be decomposed (Harhira, 2007; James, 2005).

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In this study, we investigated the photodegradation of Toluene at parts per million levels with reference to the typical indoor air pollutant concentrations in environment.

MATERIALS AND METHODS

The test set-up is based on the Japanese standard JIS TR Z 0018 "Photocatalytic materials –Air purification test procedure".

Equipments:

The central part of the experimental setup used is a gas reactor allowing a sample of size 10× 20 cm^2 to be fixed. The reactor is made from materials which are non-absorbing to the applied pollutant and can hold up UV-A light of high irradiance. The reactor is tightly closed with a glass plate made from borosilicate glass allowing the UV-A radiation to pass through with almost no conflict. Two 10 W UV-A fluorescent lamps (black lights) with wavelengths 366 nm were used to supply photo irradiation to activate the photo catalyst. The schematic illustration of the reactor cell and the test setup is specified in Figure 1.

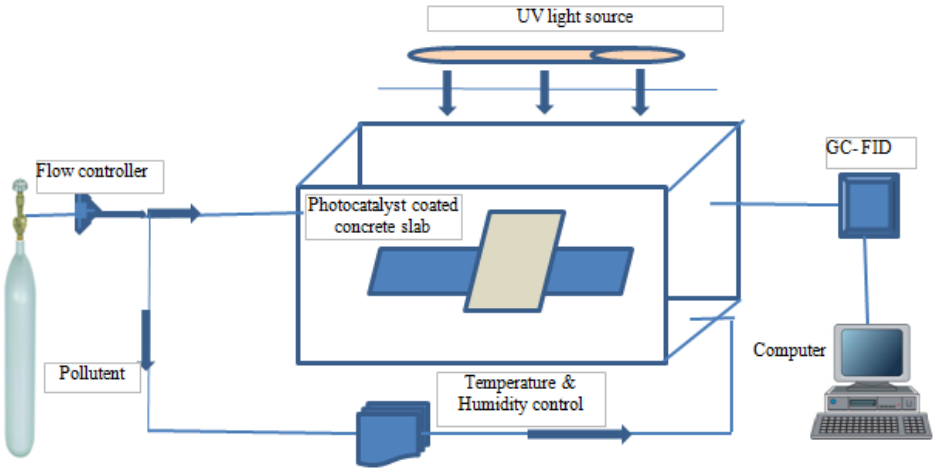

Fig. 1: Schematic diagram of the experimental setup.

Materials:

The $LiNbO_3$ powder CAS12031-63-9 from Sigma-Aldrich was used as the photocatalyst in this study. The pollutant Toluene from Sigma-Aldrich and used without further purification.

An irradiation experiment of pollutant was carried out by spraying 5 mg/L toluene solution with immobilized $LiNbO_3$ at room temperature (25 + 2^oC) for 6 hours unless otherwise stated. For the effect of contact time and initial pollutant concentration, at predetermined time intervals, approximately 5 ml of the gas was withdrawn from the reaction chamber. The effect of depth coating was performed by varying the amount of coating, 0.25, 0.50 and 0.75mm. The concentration of pollutant in the reaction chamber was determined using a GC-FID.

RESULT AND DISCUSSIONS

A typical result of the test is given in Figure 2. The inlet concentration is equal to 50 ppm. As soon as the UV light is put on, the concentration drops with approximately 40 %. After 5 hours of illumination, near about 80 % of toluene concentration is degraded.

The maximum degradation of pollutant depends on the material itself, on the size of the surface exposed, on the concentration of toluene, on the light intensity and the ambient temperature.

By increasing the depth of coating maximum degradation of toluene is obtained. This is very promising for the extrapolation to the situation in situ. By increasing the time of contact or increasing the surface over which the air flows, the reduction will be even more significant. Figure 3. show that degradation rate of toluene in $LiNbO_3$ is higher than that of TiO_2. Under the experimental conditions of this study, TiO2 catalyst behaved less active than the $LiNbO_3$.

As shown in figure, the photocatalyst (TiO_2 & $LiNbO_3$) samples show relatively high degradation ability for toluene while a decrease trend is observed after 4 hours. The degradation ability increases rapidly in the first hour and reach stability within 6-7 hours for TiO_2 and $LiNbO_3$ catalysts. This result confirms that the organic pollutant is easier to be degraded through photocatalysts. Similar results have shown by (Ibram Ganesh, 2011) in his study of chlorine radical and hydroxyl radical reactivates with toluene and ethyl benzene and found that ethyl benzene

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is more reactive than toluene with chlorine radicals, but much closer reactivates between toluene and ethyl benzene are observed with only present of hydroxyl radicals.

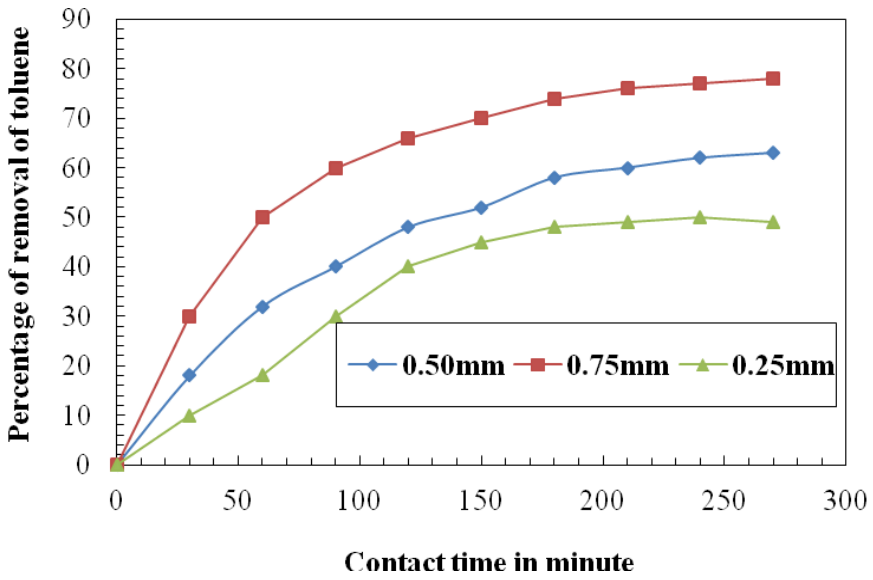

Fig. 2: Effect of depth of coating for the photo degradation of Toluene**.**

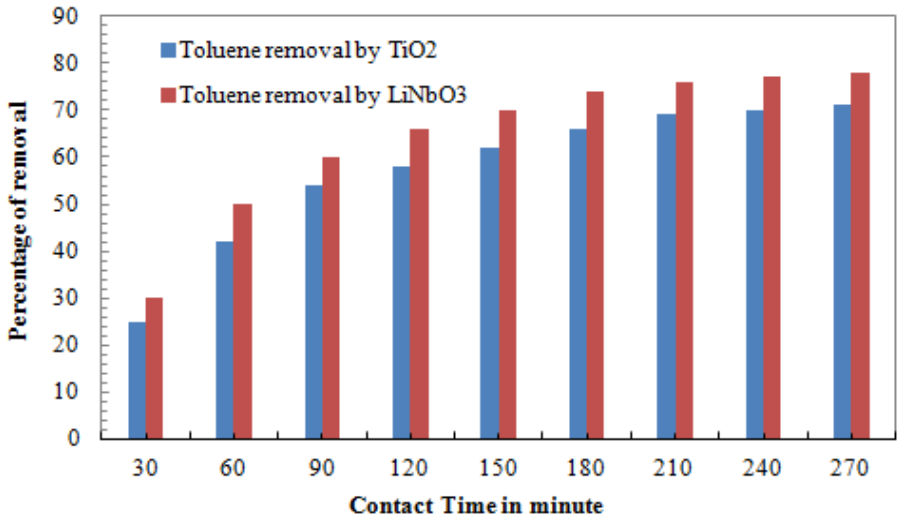

Fig. 3: Comparison of toluene degradation in coating with $LiNbO_3$ & TiO_2

Conclusion:

From this study, it is evident that the $LiNbO_3$ is capable in removing Toluene under the illumination of UV. The results revealed that the $LiNbO_3$ plays an important role in determining the photocatalytic degradation efficiency of Toluene. Further studies on the intermediates produced in the photodegradation process will be carried out to ensure that no undesirable hazardous compounds were formed before complete degradation takes place. Finally, the possibility to repetitive usage of $LiNbO_3$ should be explored and concentrated in future study.

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Conflict of interests:

The authors declare that there is no conflict of interests regarding the publication of this paper.

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