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Full Length Research Paper

Titanium dioxide as photocatalyses to create self cleaning concrete and improve indoor air quality

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Air inside buildings can be more polluted than outdoor because there are various sources of pollution in some big cities. This paper presents the results of a study on the efficiency of contributing air cleaning agents such as Titanium dioxide (TiO_2) into the technique of producing concrete composite panels, using local waste materials for solving the problem of carbon dioxide (CO_2) in indoor air buildings. Factors which would have an effect on the performance of the panel were studied, including the porosity of panel, different types of waste materials and types percentage of TiO_2 used within the mix design. The degradation process under laboratory conditions was studied using chemiluminescence analysis method for measuring the performance of photocatalytic active concrete products. The results show that the photo degradation of CO_2 is related to the porosity of the sample; when the porosity of sample was increased, the CO_2 had removal ability.

Key words: Concrete composite panel, indoor air quality, titanium dioxide, photocatalyses, degradation, carbon dioxide.

INTRODUCTION

Indoor air quality has received immense attention in the early 1990s. The indoor air quality in any building can be compromised by microbial contaminants (mold, bacteria, and gases), chemicals (such as, carbon dioxide, formaldehyde), allergens, or any mass or energy stressor that can induce health effects (John et al., 2000). The concentration of carbon dioxide (CO_2) in Earth's atmosphere is approximately 390 ppm by volume as of 2010, and rises by about 1.9 ppm/yr. The present level is higher than at any time during the last 800 thousand years and likely higher than in the past 20 million years (Hoffmann and Martin, 1995). Hence, a clean indoor air is important for the well-being and health of people because most of people spend 90% of their time indoors especially the young, the elderly and those who are chronically ill.

USEPA (1995) identified indoor air pollution as one of the top environmental risk. Additionally, the construction industry is the major source of air pollution; transportation for a high population density of people and the numerous tall buildings hinder and prevent the dispersion of air pollutants generated by a high concentration of vehicles at the street level (Li et al., 2001). Several studies are apparent that there is a need to remove pollutants, such as carbon dioxide (CO_2) and nitrogen oxides (NO) from the atmosphere; Not only do these gases pose a threat to health, they are also causing degradation to many inner city buildings (Jones, 1999;). This study attempts to lower these emissions by using cleaner air such as photo catalyst, which is a way of removing pollutants from the atmosphere to be the most feasible option to improve indoor air quality to develop a local low-cost building-panel system suited to their tropical climate.

Over the last 10 years, the scientific and engineering interest in the application of semiconductor photo catalysis has grown exponentially. In the areas of water, air, and wastewater treatment alone, the rate of publication exceeds 200 papers per year, averaged over the last 10 years (Poon et al., 2001). The use of nanotechnology to important advanced oxidation effect on materials via photo catalysis is a novel approach.

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Abbreviations: FBA, Furnace Bottom Ash; **OPC,** ordinary portland cement; **RA,** recycled aggregate.

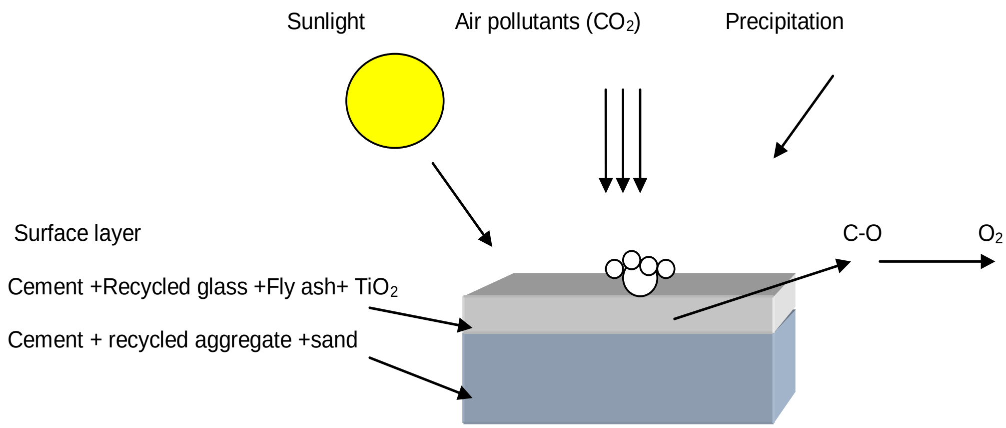

Figure 1. The design of the photocatalytic paving blocks materials and methods.

Oxidation eliminates, like (TiO_2) photo catalyst has received significant interest in recent years due to its fascinating properties, such as electronic, optical, and UV absorption (Kawashima and Masuda, 1994). Recently, photocatalytic oxidation has been shown to be a promising and effective technology for pollution control (Yu et al., 2002; Fujishima et al., 2000; Obuchi et al., 1999 and Peral et al., 1997). However, (EPA's, 1987; Luo and Ollis, 1996; Kim and Hong, 2002) studies showed that the rate of PCO decreased with decreasing pollutant concentration. In addition, at high humidity levels, water vapour competed with TiO_2 for adsorption sites which further decreased the rate of PCO. Scientific studies on photo catalysis started about two and a half decades ago. A chemical material such as Titanium dioxide (TiO_2), which is the one of the most basic materials in our daily life, has emerged as an excellent photocatalyst material for environmental purification. Titanium dioxide, have already been tested in Japan for concrete paving materials that can facilitate a photocatalytic reaction converting the more toxic forms of air pollutants to less toxic forms, for example, CO_2 and NO (Anpo and Takeuchi, 2003) and (Murata et al., 2002). The design of the photocatalytic paving block is shown in Figure 1. Fujushima et al. (1999) note that under the illumination of ultraviolet light, photocatalysis shows diverse functions, such as the decomposition of air and water contaminants and deodorization, as well as self cleaning, antifogging, and antibacterial actions. Practical applications of photocatalysts have rapidly expanded in recent years. Photocatalytic materials for indoor purification are in urgent demand because energy and labour saving advantages have been realized when applied to building construction materials in large cities where urban air pollution is very serious (Yoshihiko et al., 1999).

The current study was designed to investigate the efficiency performance of photo catalytic materials such as Titanium dioxide on the technique of producing concrete composite panels, using local waste materials for solving the problem of the increasing rates of carbon dioxide (CO_2) in indoor air buildings.

MATERIALS AND METHODS

Preparation of materials

Cement material that is used in this study is an Ordinary Portland Cement (OPC) commercially available in Malaysia. Furnace bottom ash (FBA) that was used is a product of coal-fired electricity generation. FBA is the coarser material that falls to the bottom of the furnace during the burning of coal (Kayabal and Bulu, 2000). Only the portion that passed through a 2.36 mm sieve will be use for making the surface layer. The recycled aggregate (RA) is also used in this study. It is a crushed C and D waste sourced from a temporary recycling facility. In the plant, the C and D waste underwent a process of mechanized sorting; only the smaller fine aggregate proportion was used for making the surface layer of the blocks in this study (BS, 1985). The maximum size of the recycled fine aggregate used is 2.36 mm. The sand that was used is fine natural river sand commercially available in Malaysia. Chemical material candidate is Titanium dioxide (TiO_2). The best source of titanium dioxide is Anatase sourced commercial available, which was used due to its high purity and accurate specifications. It is commonly used in the industry and research community, hence would be useful for comparison with works of other materials (Poon and Cheung, 2007).

Sample proportions

The samples were fabricated in steel moulds with internal dimensions of 20 × 10 ×5 cm. The wet mixed materials were weighed between 400 and 500 g for each sample depending on the different materials. The steel moulds were filled by hand compaction. After 1 day, the samples were removed from their moulds and tested for CO_2 photo degradation at 15, 30, and 60 days with GC gas equipment.

Mix proportions

Mixes were prepared with RA, TiO_2, water and sand. This study focuses on usefulness of recycled materials, so a series of mixes were prepared to find out the effects of titanium dioxide and proportions on CO_2 removal efficiency. Mixes with varying cement

Table 1. Mixes prepared with different materials.

Relative proportions (by weight (g))					
Ratio	Cement	RA	Sand	Water	TiO_2
1:2	1.0	2.0	0.5	5.0	0.50
1:2:5	1.0	2.5	0.6	5.4	0.50
1:3	1.0	3.0	0.7	6.0	0.50
1:2	1.0	2.5	0.5	6.5	0.50
1:2:5	1.0	3.0	0.6	7.9	0.50
1:3	1.0	3.5	0.7	8.3	0.50

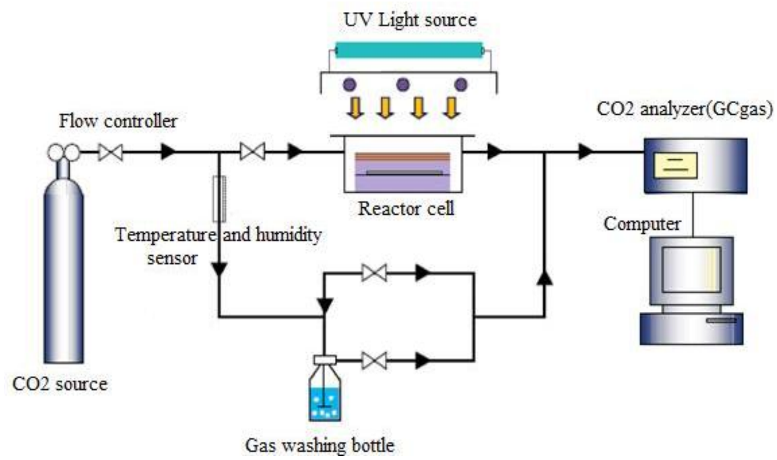

Figure 2. Schematic diagram of the experiment setup.

to aggregate ratios, ranging from 1:2, 1:2:5 and 1:3 was prepared. A large amount of the mixes was prepared by utilizing aggregate sizes from 300 to 2.36 mm. The varying amount of TiO_2 were studied by preparing samples with the TiO_2 Anatase content ranging from 0.06 to 0.08% as shown in Table 1.

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. The surface of the specimen is fixed parallel to the covering glass inside the reactor, leaving a slot of 0.3 cm for the gas to pass through it; the sample gas only passes the reactor through the slot between the sample surface and the glass cover in longitudinal direction. All structural designed parts inside the box are to allow laminar flow of the gas along the sample surface and to put off distribution. Two 10 W UV-A fluorescent lamps (black lights) with wavelengths 366 nm were used to supply photo irradiation to activate the photo catalyst. Two types of sensors were used, temperature and humidity sensor. The tool that was used to analyse the result of CO_2 removal efficiency by computer is GC gas. The schematic illustration of the reactor cell and the test setup is specified in Figure 2.

RESULTS AND DISCUSSION

Influence of porosity of the panel surface layer on carbon dioxide removal

Micropore areas increased averagely from 1.5 to 5.5 m^2 g^{-1} according to BET surface areas, as raising photocatalytic content up to 1 mol%. The samples showed the highest microporosity, 10.02 and 10.55 $m^2 g^{-1}$, respectively. The higher framework microporosity leads to higher interaction adsorbents between the TiO_2 and CO_2 molecules, therefore, resulting in the gradual enhancement in carbon dioxide-adsorbed amount up to the optimal capacity of 8% every 15 min. These results are consistent with numerous reported literatures on bi-porous materials (Yu et al., 2002). The microporosity also influences on the adsorption behaviour for carbon dioxide gaseous via the relative diffusion control. However, once again, the microporous regions dominated the adsorb ability in view of the reduction in micropore areas, resulting in the faster diffusion and the corresponding lower carbon dioxide-adsorbed amounts than those of 5% doped materials. It obviously indicated that the frame-work microporosity plays an important role in controlling

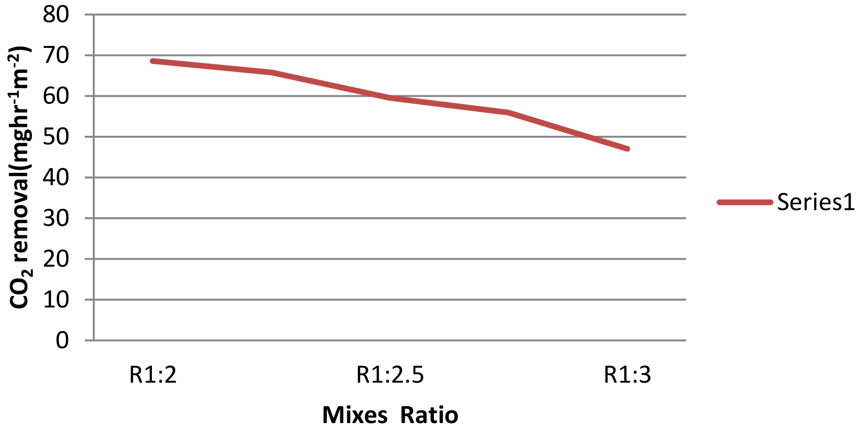

Figure 3. Influence of TiO_2 and local material on carbon dioxides photo degradation under UV light after 1 week.

diffusion mechanism of the adsorbate molecules over photocatalytic materials directly relating to the adsorb-ability. Similar observations were also acknowledged by Peral et al. (1997). The results show that porosity of the surface layer is important, which efficiently increased the area available to reacts with the pollutants. The porosity of the surface layer was affected by the type of materials with which they were prepared. Materials with a lower density led to a higher porosity of the panels. The particle size distributions of the materials used also affected the porosity of the panels.

Influence of TiO_2 and local material on carbon dioxide photo-degradation under UV light

The results of CO_2 photo degradation as shown in Figure 3 indicates that, the RA mixes achieved a much higher CO_2 removal compared to the sand mixes under UV light after 1 week from the test. This is probably due to the porous nature of RA compared to that of sand. The results also indicate that, the CO_2 removal slightly increased when FBA was not included in the mix design. This is due to the higher porosity of FBA particles which was exemplified by its relatively low specific density compared to those of sand and RA.

Effect of particle size of aggregates on carbon dioxide photo-degradation

The specimens prepared with different aggregate sizes was believed to affect their ability to remove CO_2 as varying the particle size distribution of aggregates would effectively change the porosity of the specimens. The specimens were divided into two groups, one was prepared with all aggregate sizes below 2.36 mm included and the other with aggregate sizes only between 300 µm and 2.36 mm included shows the specimens tested at 1 and 2 weeks with cement to aggregate ratio of 1:3. The results indicated that the specimens prepared with aggregate sizes between 300 µm and 2.36 mm (the more absorbent specimens) achieved approximately 6% higher CO_2 removal during the 2 weeks from the test shown in Figure 4.

Lahl and Lambrecht (2008) found the same result of the applications of different type's photo catalytic pavement blocks, as is applied in Antwerp, Belgium, in Bergamo, Italy and in Japan. According to Yoshihiko et al. (1999) and Robinson and Nelson (1995), vertical applications found in the Netherlands (as part from the IPL project) shows the dependence of the CO_2 removal on the irradiance for low values of irradiance based on own measurements on paving block samples power function describes the relation between the irradiance E and the different concrete mixes of the samples achieved degradation rates for all samples continents aggregate sizes below 3.80 mm.

Effect of porosity on carbon dioxides photo degradation

The factors that can influence on the CO_2 removal showed earlier were all associated with porosity. Figures 5 and 6 show the measured porosity compared with CO_2 removal of some of the selected mixes within the 4 and 5 weeks from the test started. A clear preference can be realized that the CO_2 removal increased with increase in porosity. Okura and Kaneko (2002) shows that the influence of the relative porosity depends to a large extent on the type of material used and the effect at the surface prevails over the oxidizing effect when high values of relative humidity are applied.

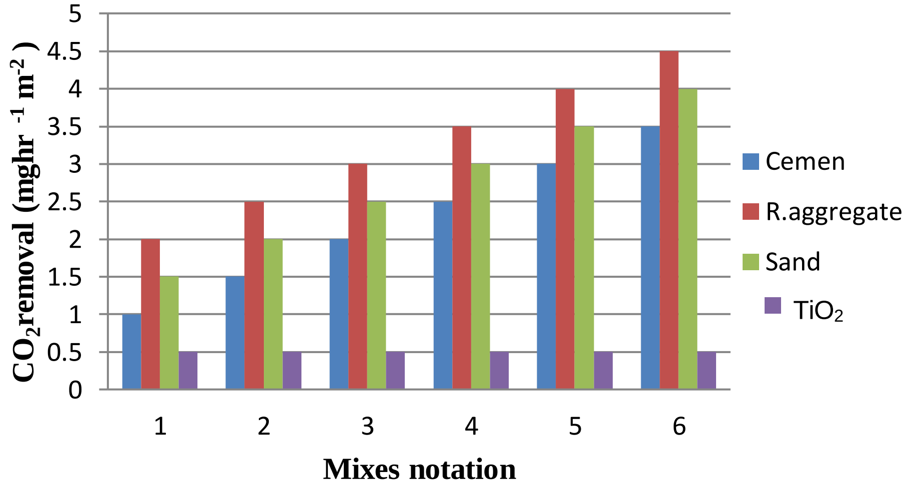

Figure 4. Influence of TiO_2 and cement/aggregate ratio on carbon dioxides photo degradation under UV light after 2 weeks.

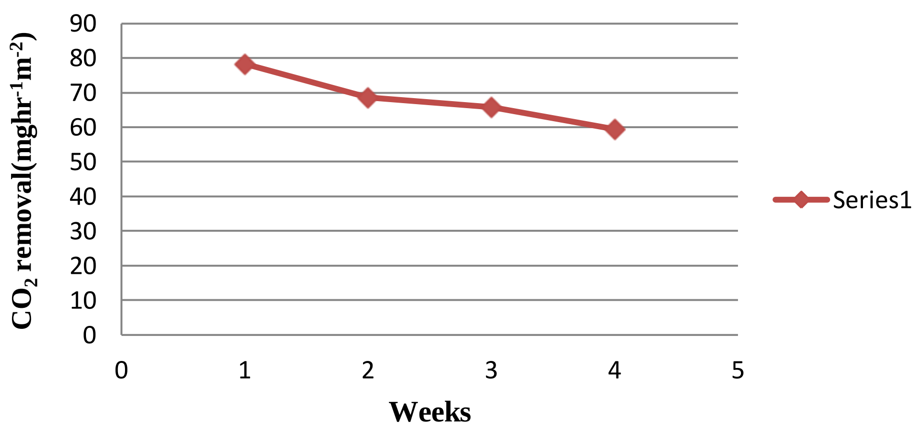

Figure 5. Influence of porosity on carbon dioxides photo degradation under UV light after 4 weeks.

Influence of carbon dioxide adsorption on the titanium dioxide particles structure

Figure 7 illustrated the SEM photomicrograph of the titanium dioxide before adsorption of carbon dioxide on the specimen's surface, the morphology of the particles are a round, lighter and systematic structure particles.

In addition, from the result observation of the morphology of titanium dioxide particles after adsorbed carbon dioxide, the particles structures are converted. The large and dark agglomerates were appeared on the forms of the particles structure of (TiO_2). The SEM photomicrograph of the titanium dioxide after adsorption carbon dioxide on the specimen's surface is shown in Figure 8.

Conclusion

This paper reports on the findings on assessing the factors which would affect the ability of the prepared surface layer of the composite panel to remove Carbon dioxides by photo catalytic activities (TiO_2).

- The primary results show that porosity of the surface layer is important, which efficiently increased the area available to react with the pollutants. The porosity of the surface layer was affected by the type of materials with which they were prepared.
- Materials with a lower density led to a higher porosity of the panels. The particle size distributions of the materials used also affected the porosity of the panels. The change

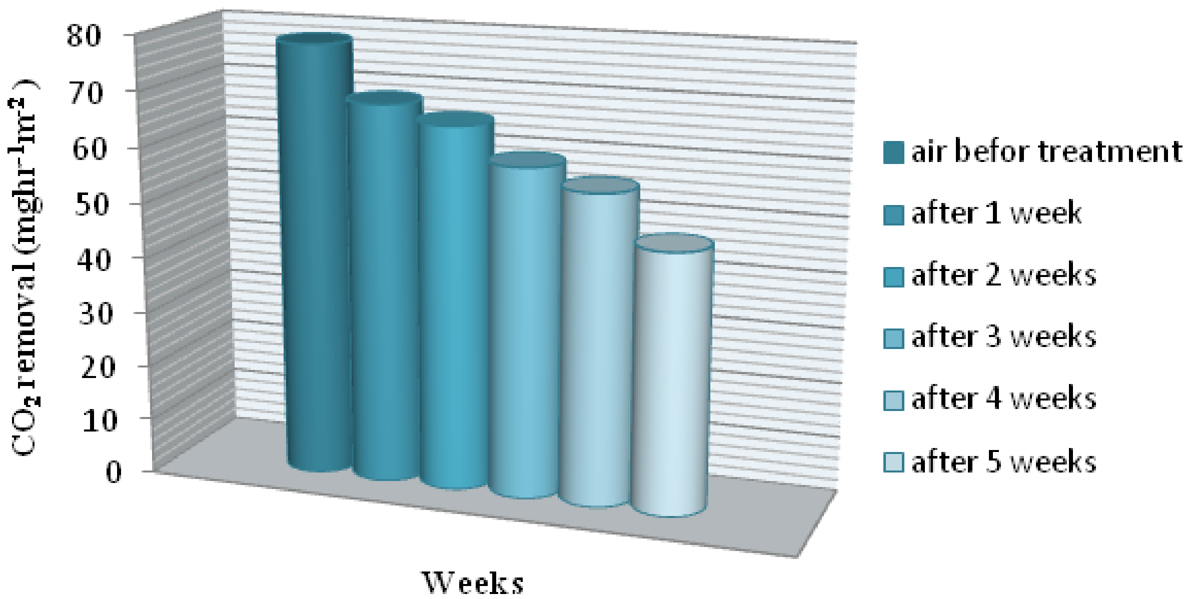

Figure 6. Influence of porosity on carbon dioxides photo degradation under UV light after 5 weeks.

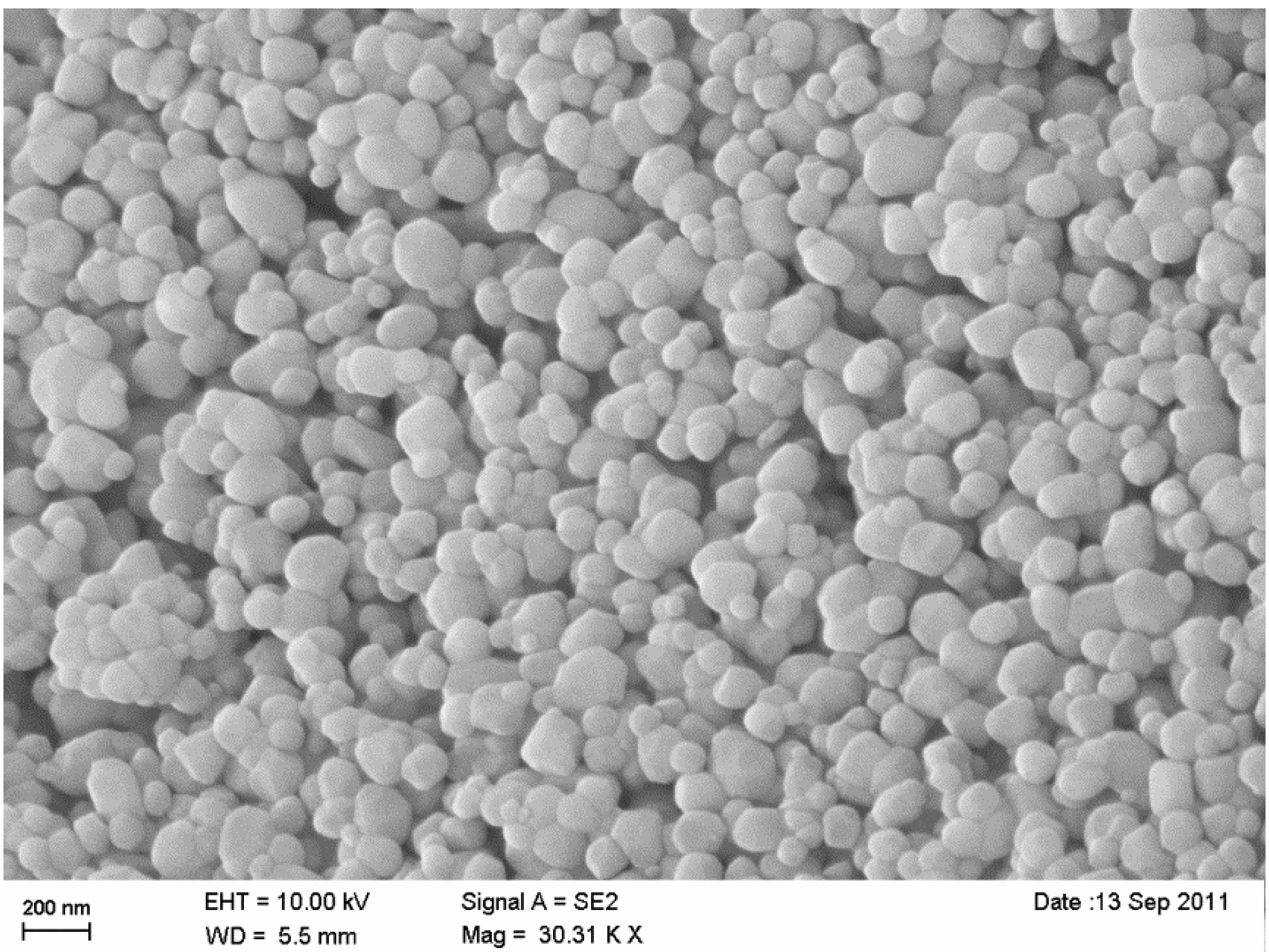

Figure 7. SEM photomicrograph of the titanium dioxide before adsorption carbon dioxide on the specimen's surface.

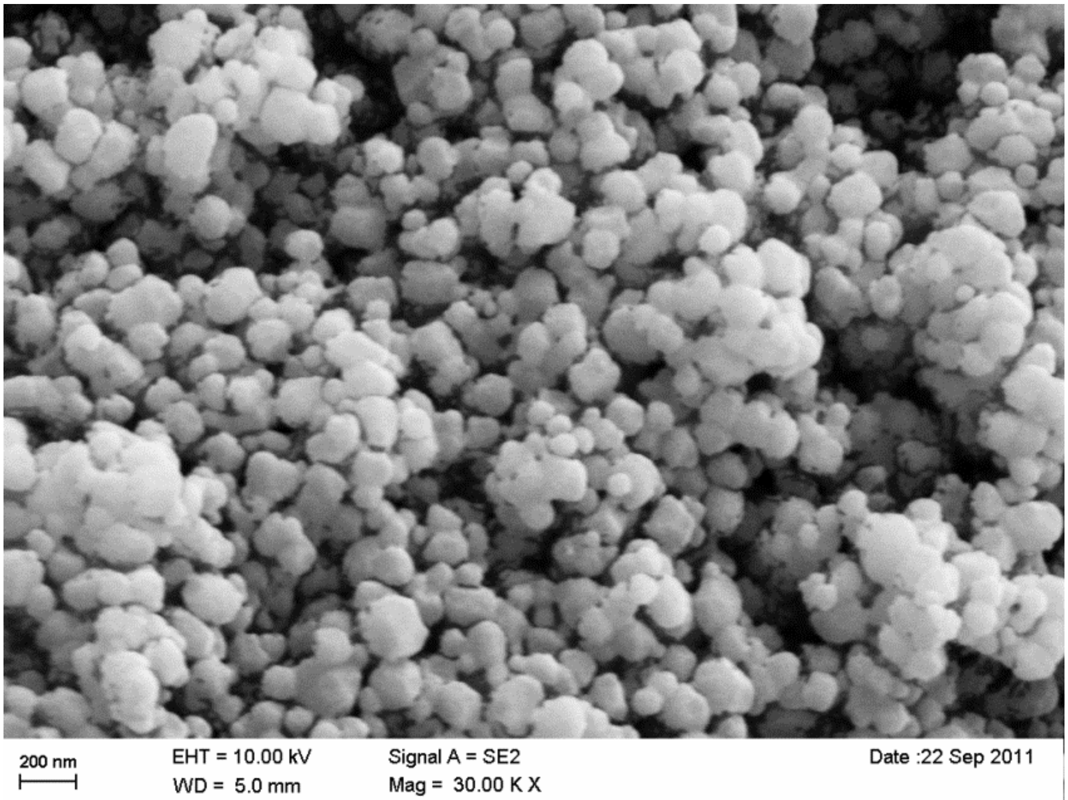

Figure 8. SEM photomicrograph of the titanium dioxide after adsorption carbon dioxide on the specimen's surface.

in the cement to aggregate ratio of the mixes had an apparent relationship to the Nitrogen oxides removal ability.

- Mixes prepared with lower cement to aggregate ratio were more effective at removing carbon dioxides. Samples that tested at different remedial ages were found to demonstrate different abilities to remove carbon dioxides.
- The results show that titanium dioxides decreased with age but the decrease stabilized at the age of 90 days. Anatas was used as the better form sourced from a commercial source; hence, it be the best photo catalytic ability for improve indoor air quality.

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