Photocatalytic degradation of NOx in a continuous bench-scale reactor using active tiles, experimental data and simulations

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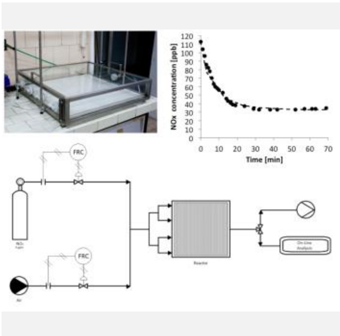

In the present work we present a new kind of gas-flow reactor able to test photocatalytic building materials in large size, optimizing the reaction conditions in order to work both with artificial conditions of irradiation (UV-A lamp) and under the direct sunlight. In particular, industrial porcelain grès tiles were tested towards the photodegradation of NO_x in air in a continuous experimental setup, either using UV lamps or using the sunlight, studying the effect of different concentration of NO_x on the building material performances first, as the effect of different light sources.

Background

Nowadays it is imperative to develop new strategies and new materials to clean the environment. Every year laws and regulations become stricter with the aim to reduce the greenhouse gases emissions and improve the quality of the air. Among all the pollutants, nitrogen oxides (NO_x), are strictly monitored all over the world and guidelines on the alarm levels of these molecules in air were published by WHO [1] and often recalled in the legislations of the single Country worldwide. Photocatalysis with titanium dioxide as semiconductor [2,3] seems to be a very promising technique to reduce the pollutants concentration thanks to its very powerful oxidation property.

One of the main problems regarding the construction materials is to find a serious and reproducible way to test them and confirm their photo-efficiency. Many reactors with different configurations have been proposed and published [4, 5, 6], but in all cases, very small sizes of the sample are tested. The ISO reactor requires a sample of 5x5 cm in size, a dimension so small in comparison to the real use of the final material. Moreover, testing conditions are often very far from the reality: too high NOx concentrations and levels of UV-A irradiation impossible to obtain on earth.

Objectives

In the present work we present a new kind of gas-flow reactor able to test photocatalytic building materials in large size, optimizing the reaction conditions in order to work both with artificial conditions of irradiation (UV-A lamp) and under the direct sunlight. In this latter case, the test can predict the real efficiency of the material when this product will be used to cover a building. As testing sample, we chose a photocatalytic porcelain-grés tile by GranitiFiandre SpA, available in the market, whose photocatalytic properties are well-known [7].

Target of the experimentation was to verify both the reactor performance and the efficiency of the photocatalytic tile to reduce the pollution and maintain the NOx level under 40 µg/m^3 (value requested by WHO for a clean air) [1].

Methods

Sample preparation and characterization

Industrial porcelain-grès tiles are manufactured under high pressure by dry-pressing fine processed ceramic raw materials with large proportions of quartz, feldspar, and other fluxes and finally fired at high temperatures (1200–1300°C) in a kiln. Commercial photoactive porcelain grès tiles by GranitiFiandre S.p.A were subsequently covered at the surface with a mixture of pure Anatase-micro-TiO_2 (1077 by Kronos) and a commercial SiO_2-based compound. To ensure the requested product stability, at the end of the preparation procedure tiles were treated at high temperature (min 680 °C) for 80 min and then brushed to remove the powder present at the sample surface and not completely stuck (samples name: WGActive). Temperature was precisely chosen to maintain the anatase form of the semiconductor and allow the vitrification of the tiles surface [8].

Photocatalytic Tests

Industrial porcelain grès tiles (60cm x 60cm x 1 cm) were tested towards the photodegradation of NO_x in air in a continuous experimental setup using a glass reactor with walls of 10 mm of thickness. The experiments were carried out either using UV lamps or using the sunlight of July and September.

The initial concentration of the NO_x (either 200 or 100 ppb) was obtained by diluting the NO_x of the cylinder with air using two different flow meters.

The pollutants concentration was monitored using chemiluminescence instrument (Serinus 40 Oxides of Nitrogen Analyser) and used to check the final conversion of the pollutant.

Results

Being the inlet NOx concentration doubled, the time needed for the stationary condition to be reached is greater (about 100 minutes). We test the same tile for more consecutive days, to check the photoactivity after several cycle, both for reproduce a normal day-working. Also in this case the results are remarkable.

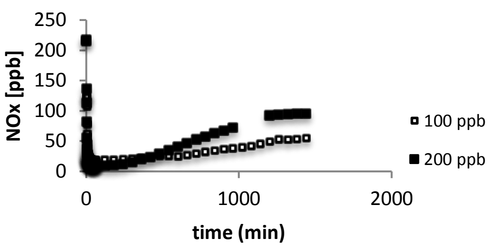

Figure 1. NO_x photodegradation under 20 W/m2 of UV light, total flowrate of 180 L/h.

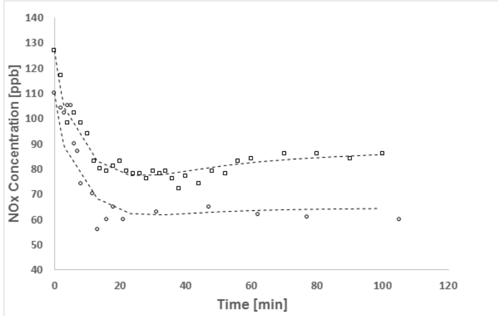

Figure 2. NOx concentration vs. Time under sunlight exposion.

These results show how the reactor performance is dependent from the light intensity. The data gathered during the July month are characterized by a greater NOx final conversion compared to the one of September. In the model, the dependency of the light intensity on time was considered linear, and the calculated values fit the experimental one.

Conclusion

Besides the demonstration of the efficacy of the WGActive tiles, we showed the operation of a new reactor able to test photocatalytic building materials in large scale. This reactor solves the problems related to real and ideal conditions, usually established when very small ISO reactors are used. Moreover, through the experiments carried out in this work, we studied the effect of different concentration of NO_x on the building material performances as well as the effect of different light sources, that is natural (sunlight) or artificial (UV light).

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