REAL SCALE TESTS OF THE DEPOLLUTING CAPABILITIES OF A PHOTOCATALYTIC SIDEWALK PAVEMENT AND A FACADE IN AN URBAN SCENARIO

M. Pujadas[1], M. Palacios[1], L. Núñez[1], M. Germán[1], J. Fernández-Pampillón[2], B. Sánchez[1], J.L. Santiago[1], B. Sánchez[3], R. Muñoz[4], F. Moral[4], G. Arias[4]

[1]Department of Environment, Research Center for Energy, Environment and Technology (CIEMAT), Madrid, Spain
[2]National University of Distance Education (UNED), Madrid, Spain
[3]Department of Energy, Research Center for Energy, Environment and Technology (CIEMAT), Madrid, Spain
[4]Alcobendas City Council, Madrid, Spain

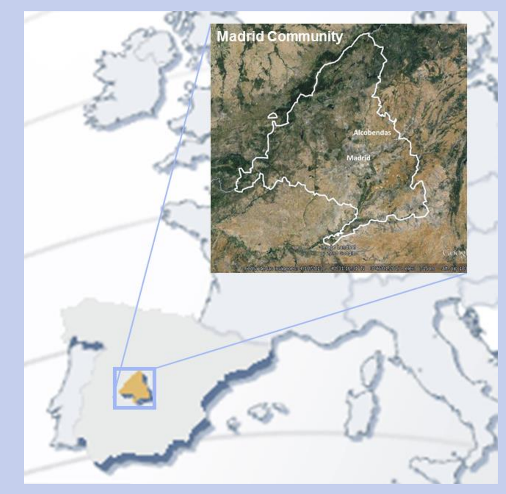
The use of photocatalytic building materials is considered a promising air pollution abatement strategy that is specially indicated for urban areas. These construction materials are treated with different TiO_2 enriched products and the photocatalytic characteristics of this semiconductor are the key of their depolluting capabilities. These performances are specifically tested and characterised in laboratory essays applying standard methodologies. Nevertheless, there is an important lack of experimental evidences demonstrating the effective removing pollution potential of these materials in real urban scenarios.

In the framework of the LIFE MINOx-STREET European project (co-financed by the EU), a strict protocol based on UNE-ISO 22197-1:2012 [1] to test and compare the potential usefulness of a variety of commercial photocatalytic materials has been followed. As a result, two photoactive coatings were selected to be applied and tested at large scale under real outdoor conditions: one for using on sidewalks and another for facades. Both products have been implemented in a model of street canyon built in an urban area of Alcobendas (Madrid, Spain) in order to assess the effect on the degradation of atmospheric nitrogen compounds.

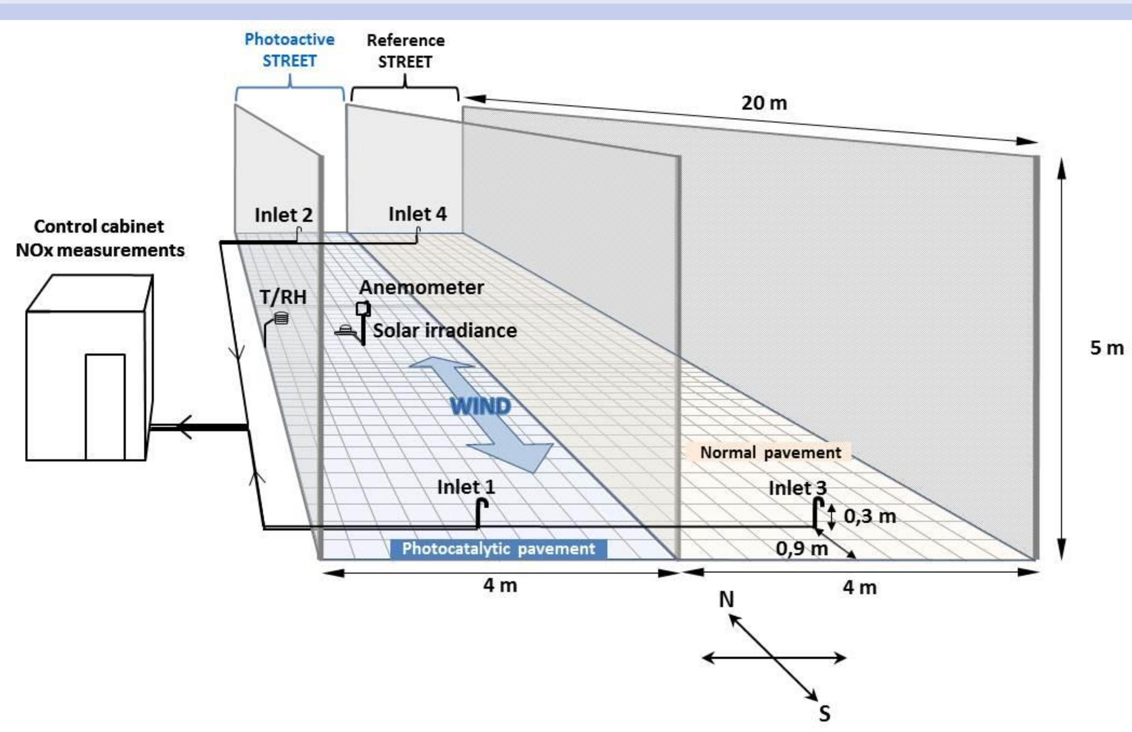
EXPERIMENTAL SITE

The depolluting capability of the selected photocatalytic materials has been assessed in a real urban scenario of Alcobendas, a municipality of the Region of Madrid. This region is located in the centre of the Iberian Peninsula and counts with the most important metropolitan area in Spain formed by Madrid city and seven other medium towns surrounding the capital.

The place selected for the experiments (marked in the image) was a double street canyon located near Avenida de Valdelaparra, a street of Alcobendas with moderate traffic.



SIDEWALK SCENARIO



Scheme of the experimental set up
Photoactive street: Sampling points 1-2 and meteorology sensors
Reference street: Sampling points 3-4
Control cabinet: Continuous measurement of NO, NO_2 (Thermo Scientific 42i)
Experimental campaign: April, 6th 2016 till June, 30th 2016

Double street canyon building

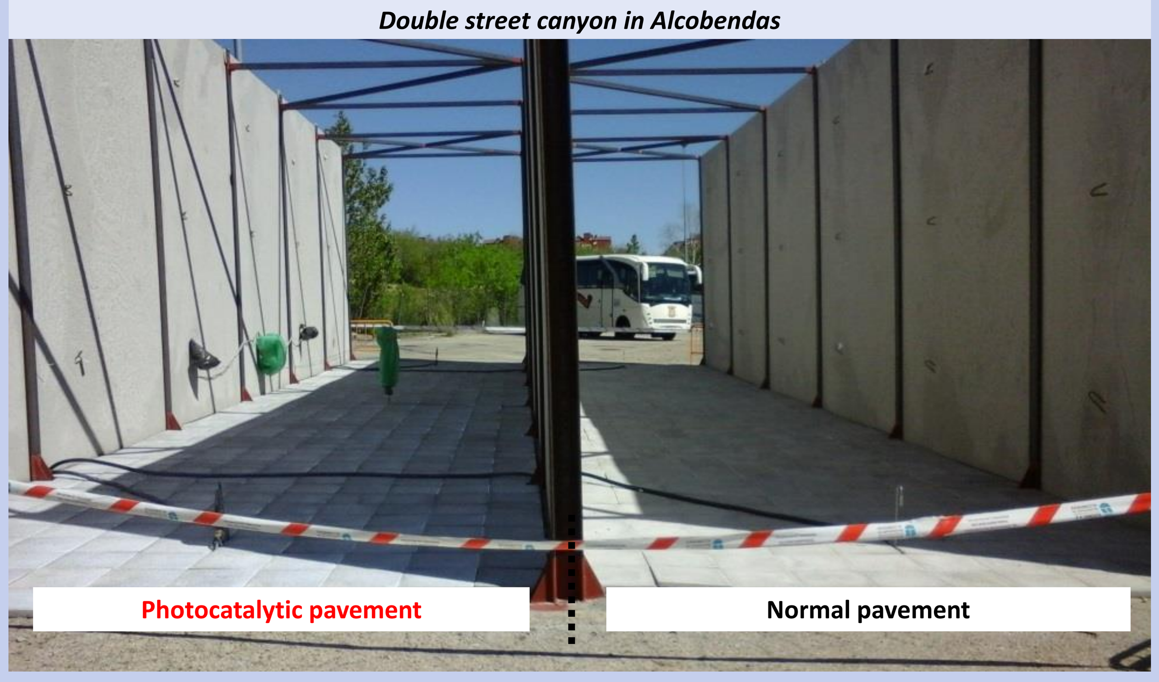
Meteorology sensors and air sampling point

Implementation of the photocatalytic coating

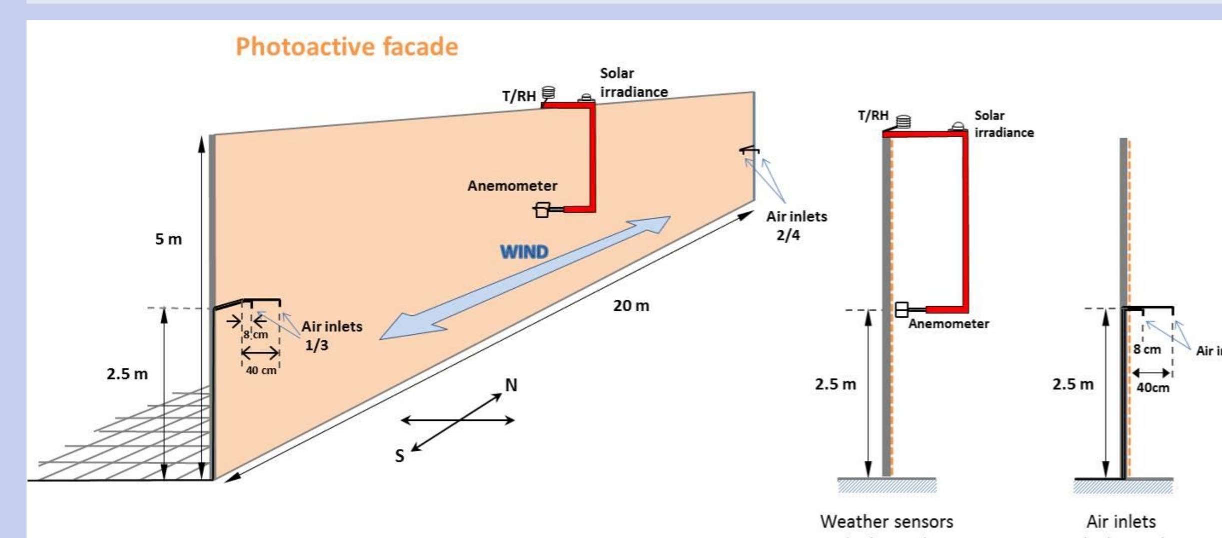
The photocatalytic material (coating) was only applied on the tiles of one of the streets, "photoactive street" (3rd May 2016). The NO depolluting efficiency was 65% under the ISO international standard [2].

The four sampling lines were implemented for the measurement of the NO and NO_2 ambient concentrations near the surfaces in order to detect and characterise the possible sink effect produced by the photocatalytic sidewalk vs. the normal situation in the reference street. The main interest was focused on those situations in which the air flow is produced along the axis of both streets in order to compute the NO_x concentration differences between the entrance vs. the exit of the streets.

Double street canyon in Alcobendas



FACADE SCENARIO



Scheme of the experimental set up

The eastern orientation of the facade allowed the ultraviolet radiation incident on the wall to be sufficient (>10 Wm^{-2} UVA) from early morning to noon (8:30-11 UTC), making possible the photocatalytic effect of the coating material to be observed during several hours.

Two measurement zones on the brick wall with two air sampling points each other were implemented. The correspondent sampling lines carried the air flows up to the control cabinet for NO_x sequential analysis. The air movements on the facade were monitored by means of suitable meteorological instrumentation placed on the geometric centre of the wall (sonic anemometer), and the solar irradiance, air temperature and relative humidity were also registered. This measurement configuration had the objective of detecting and characterising the appearance of possible NO_x concentration horizontal and/or vertical gradients on the facade as a consequence of the presence of the photocatalytic coating.

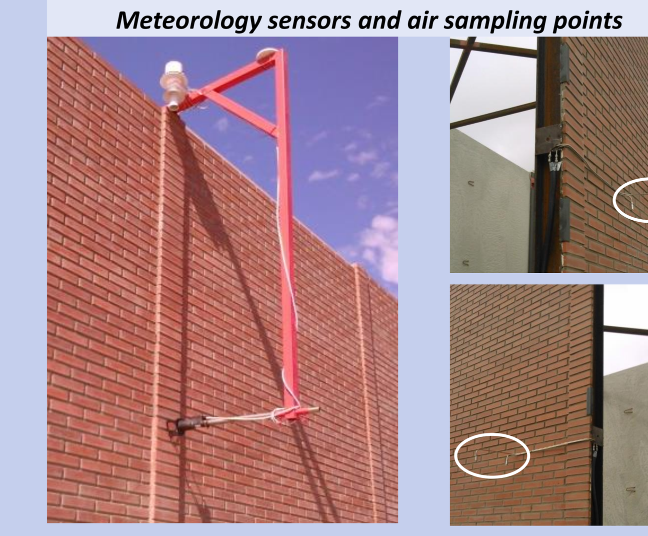
Experimental campaign: November, 3rd 2016 till December, 16th 2016

Photocatalytic facade in Alcobendas

A mobile monitoring station (marked in the image) was installed near the street canyon for the continuous measurement of NO, NO_2 and O_3 concentrations and meteorological parameters in both scenarios measurement in order to document the evolution of the physical chemical characteristics of the air mass existing in the zone and obtain fundamental information for a correct interpretation of the results.

Brick wall building on east facade of the street canyon

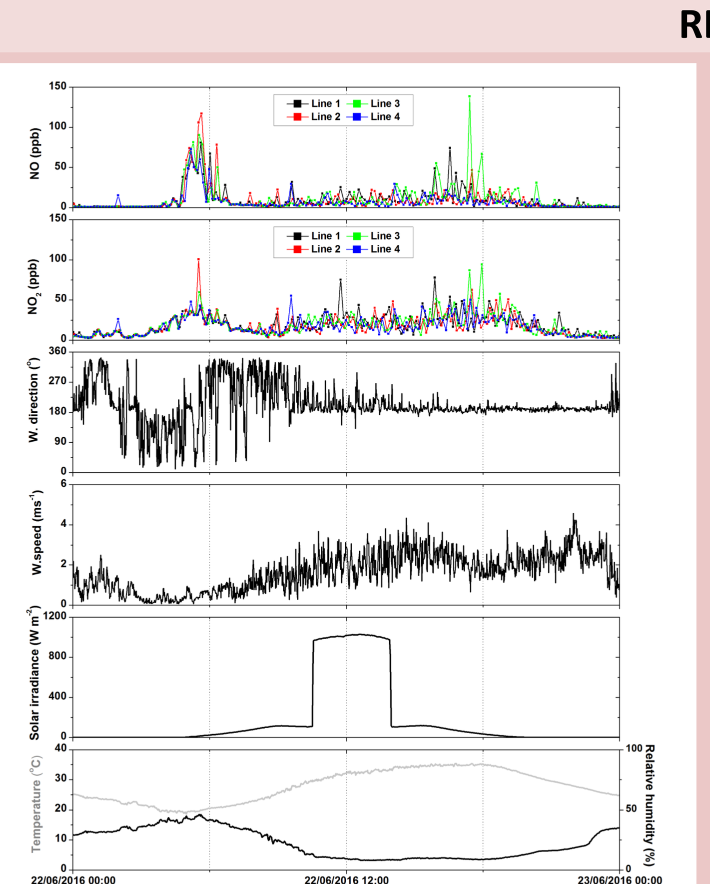
Meteorology sensors and air sampling points



Implementation of the photocatalytic coating

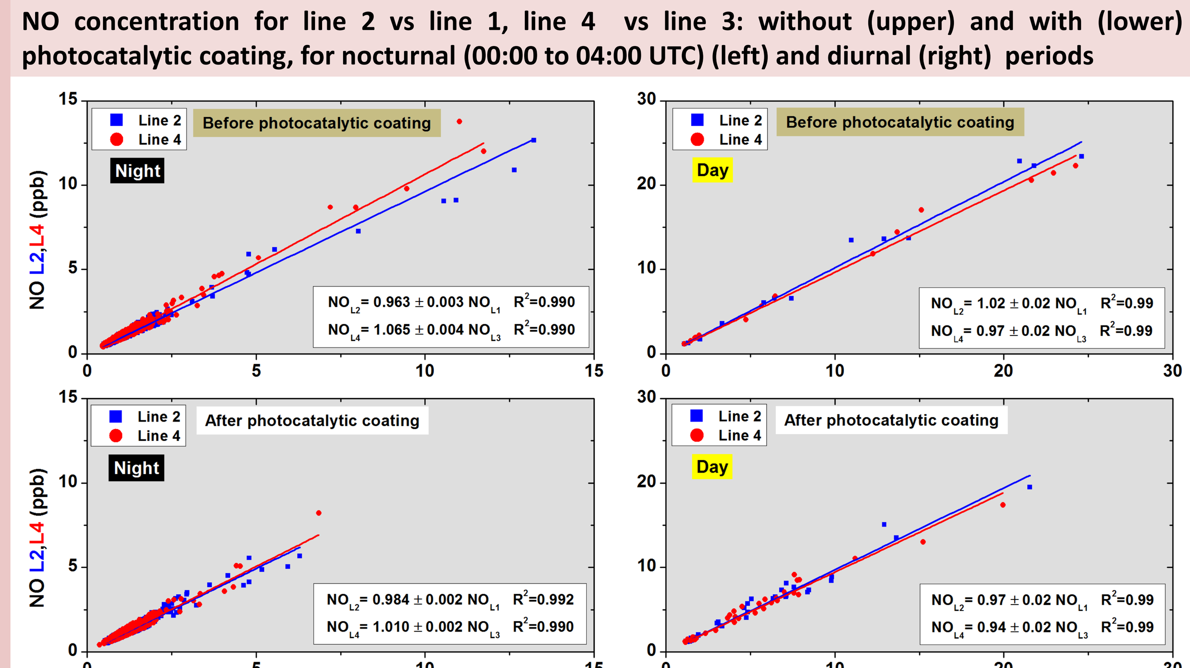
The photocatalytic material (coating) had shown a NO depolluting efficiency of 27% under the ISO international standard [2].

RESULTS: SIDEWALK SCENARIO



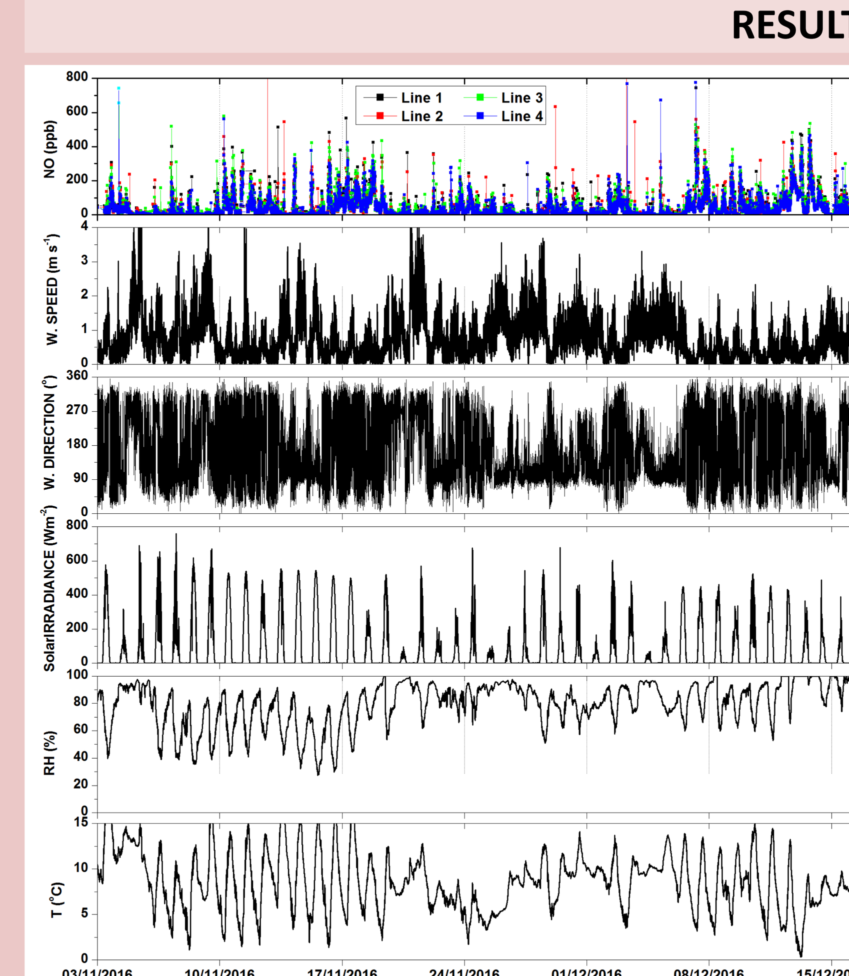
Example of NO measurements along the two street canyons (sampling lines 1 to 4) and meteorological parameters registered in the photoactive street. One minute average data allow detecting the presence of high NO and NO_2 concentration levels associated to almost every vehicle emissions in the near road. Both streets were mostly illuminated during the central hours of the day with a prevalence of south-north flows in the area, that is, parallel to the axis of the streets.

NO concentration for line 2 vs line 1, line 4 vs line 3: without (upper) and with (lower) photocatalytic coating, for nocturnal (00:00 to 04:00 UTC) (left) and diurnal (right) periods

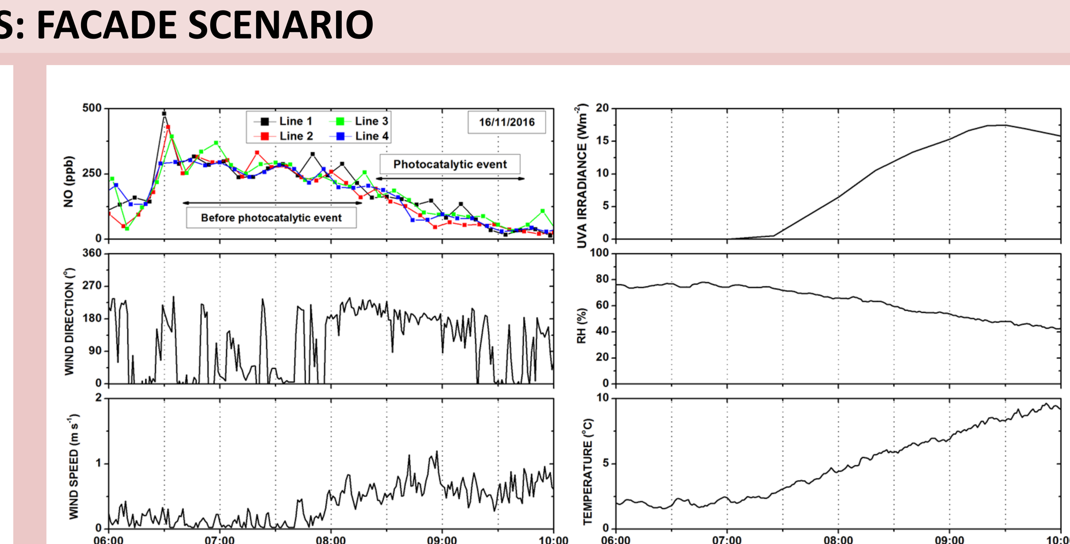


The influence of instantaneous NO direct emissions from traffic were avoid by only using those pairs of values with ratios NO_{Line1}/NO_{Line2}, NO_{Line3}/NO_{Line4} in the range of ±20 %.
Moreover, the NO diurnal concentration data were filtered selecting those periods with favorable meteorological conditions [3]: solar irradiance>400 Wm^{-2}, relative humidity<65 %, 0.5<wind speed<2.5 ms^{-1} and 160º <wind direction<200º, sector from which air masses presents the highest pollutant concentration levels. The NO concentrations registered from the sampling lines 2 and 4 were correlated against the corresponding values from the line 1 and 3, respectively. It was expected that before implementing the photocatalytic coating the four sampling points were quite similar among them and that similarity would disappear from the time the photocatalytic coating was implemented.
The slope values for nocturnal and diurnal periods before and after implementing the photocatalytic coating are actually very similar and without compatible features with any NO sink effect.

RESULTS: FACADE SCENARIO



NO_x concentration measurements results showed the influence of near NO_x emissions from traffic. Meteorological parameters showed that the air masses from the north/south component generate a well-defined flow along the facade, which allowed suitable comparisons between the NO_x concentrations measured at both ends of the wall (lines 1 and 3 in the southern sampling zone, lines 2 and 4 in the northern one) in order to characterise the possible depolluting effect.



An exhaustive study of the situations along the measurement period shows that the meteorological conditions that took place on November 16th, 2016 (high solar radiation, low wind speeds of mainly southern component) provided a good chance for detecting the photocatalytic depolluting effect. During that day air pollutants were accumulated for several hours in the early morning as evidenced by the high levels of NO concentration measured at the four sampling points. A slow ventilation process began after sunrise. A meticulous inspection of the NOx concentration data during the daytime period 6:40 to 9:40 UTC allowed isolating a possible NO reduction event due to the presence of the photocatalytic material.

Ratio NO	Before photocatalytic event	During photocatalytic event
Line 2 / Line 1	0.98	0.79
Line 4 / Line 3	0.94	0.85
Line 1 / Line 3	0.98	0.99
Line 2 / Line 4	1.02	0.91

The ratio of the mean values of the NO concentration obtained after the data process for the four sampling points before and during the photocatalytic event indicates the presence of an horizontal gradient of NO concentration near the surface wall. Such gradient could be reasonably attributed to a sink effect due to the presence of the photocatalytic material on the facade.

***CONCLUSION*:** *Photocatalytic effect has only been observed during a short period of time and under specific ambient and meteorological conditions (facade scenario). The main reasons that have prevented to unequivocally detect the development of the sink effect on the NOx on both real scenarios are: the small magnitude of the photocatalytic effect at macroscopic scale and the disturbances induced by recent emissions from traffic close to study areas.*

REFERENCES

1. International standard ISO 22197-1:2007, 2007, ISO, Geneva.
2. Palacios M., L. Núñez, M. Pujadas, J. Fernández-Pampillón, M. Germán, B. S. Sánchez, J. L. Santiago, A. Martilli, S. Suárez and B. S. Cabrero, 2015a: Estimation of NOx deposition velocities for selected commercial photocatalytic products. WIT Transactions on The Built Environment, 168,12 pp.
3. Palacios M., S. Suárez, L. Núñez, B. Sánchez, M. Pujadas and J. Fernández-Pampillón, 2015b: Influence of parameters on the photocatalytic oxidation of nitric oxide at the surface of titanium dioxide-modified concrete materials. Int. Conf. on Chemical and Biochemical Engineering, Paris, France, July 20-22. ISBN: 978-84-944311-1.

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