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Test report

UNI 11484 standard: Determination of photocatalytic activity with the tangential flow method - Abatement of nitric oxide (simplified test)

for

BLG LTD

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Torino, January 10, 2020

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1. GENERAL TEST CONDITIONS

The photocatalytic NO/NO_x abatement tests were carried out using the method described in UNI 11484 (Determination of photocatalytic activity with a tangential continuous flow method - Abatement of nitric oxide - March 2013). The method follows the European Union technical specification CEN/TS 16980-1:2016 "Continuous flow methods – Part 1: Determination of NO in the air by photocatalytic materials".

The tests were carried out with a simplified procedure, i.e. when the condition of stability of the concentrations measured under irradiation was reached or the maximum irradiation time was reached (according to the UNI 11484 180 minutes), the flow rate was not changed within the reactor, thus ending the test under these conditions.

The determination of the NO/NO_2 content in the flow was carried out using an APNA 370 chemiluminescence detector (serial number WWSBNNW6). The measuring reactor had an internal volume of 3.6 dm^3. The mixing inside the reactor was guaranteed by a compact axial fan EBMPAPST 612 JH (dimensions 60×60×32 mm) that provides a nominal flow equal to 70 $m^3 h^{-1}$.

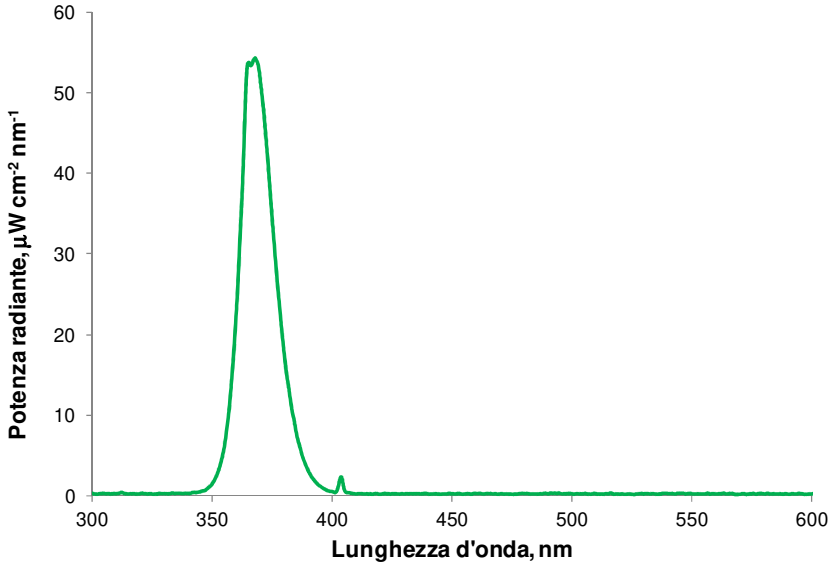

Figure 1 Emission spectrum of the Philips PL-S 9W / 2P BLB lamp. The radiant power was measured in the same position in which the sample is housed by placing the Pyrex glass cover for closing the measuring reactor between the lamp and the sample.

The irradiation took place with two different irradiation systems. In the first case, according to the indications of the UNI 11484 standard, the sample was irradiated in the UV by means of a set of two Philips PL-S 9W/2P BLB fluorescent lamps whose emission spectrum is shown in Figure 1. The intensity of the radiation incident on the sample was **10 W m^{-2}** between 290 and 400 nm.

In the second case, at variance with the standard UNI 11484, it was used a LED illuminator (6500 K color temperature), assembled at the laboratories of the Department of Chemistry of the University of Turin, devoid of UV emission. The spectrum of this source (Figure 2) was characterized as shown below. The irradiance on the sample surface was **250 W m^{-2}** between 400 and 800 nm.

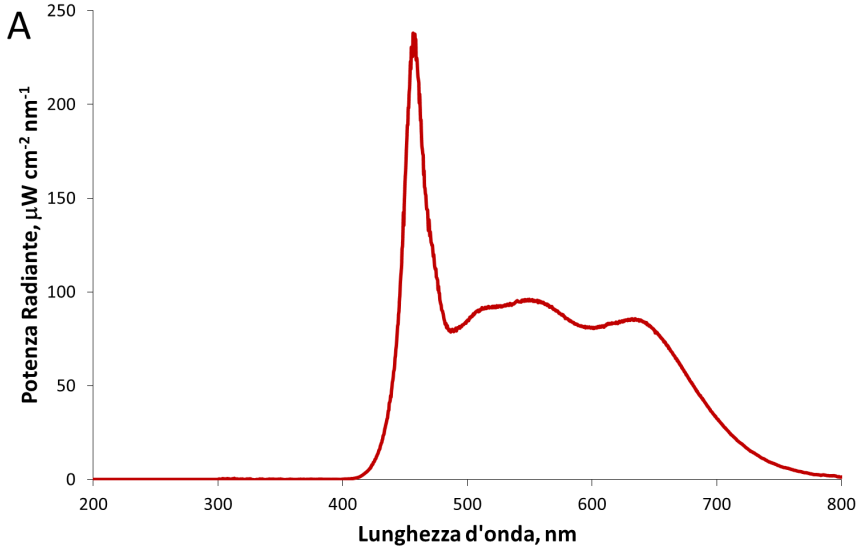

Figure 2. Emission spectrum of the LED lighting system (6500 K color temperature). The radiant power was measured in the same position in which the sample is housed by placing the Pyrex glass cover for closing the measurement reactor between the lamp and the sample.

The irradiance at the surface of the samples with the two employed irradiation systems was evaluated spettroradiometrically, through the use of an Ocean Optics USB2000 + UV-VIS spectrophotometer equipped with an optical fiber having a diameter of 400 µm and length equal to 30 cm, and equipped with a cosine corrector (Ocean Optics CC-3-UV-T, PTFE optical diffuser, spectral range 200-2500 nm, external diameter 6.35 mm, field of view 180 °). The spectroradiometer was calibrated with an Ocean Optics DH-2000-CAL Deuterium-Halogen Light Source for UV-Vis-NIR measurements, calibrated in turn in absolute irradiance by the seller (Radiometric Calibration Standard UV-NIR, calibration certificate # 2162).

2. SAMPLES

The samples (delivered directly by the client to UNITO on 9/12/2019) are two identical ceramic tiles (dimensions 10 cm × 10 cm × 9 mm) with a potentially photoactive white paint deposited on one of the faces, whose photocatalytic properties are the subject of this document.

The tests in accordance with the UNI 11484 standard ("simplified" test) were performed on the samples as such without any pretreatment.

The list of tested samples, with the respective irradiated surface area and an indication of the type of radiation used during the test, is reported in Table 1. A photograph of the tested samples is shown in Figure 3. One sample was used for the test with UV irradiation, the other for the Visible irradiation test.

Table 1. Samples analyzed.

Sample	Sample description	Irradiation	Area, cm^2	Pre-treatment
BLG – UV	Ceramic tile	UV	103	None
BLG – Vis	Ceramic tile	Visible	104	None

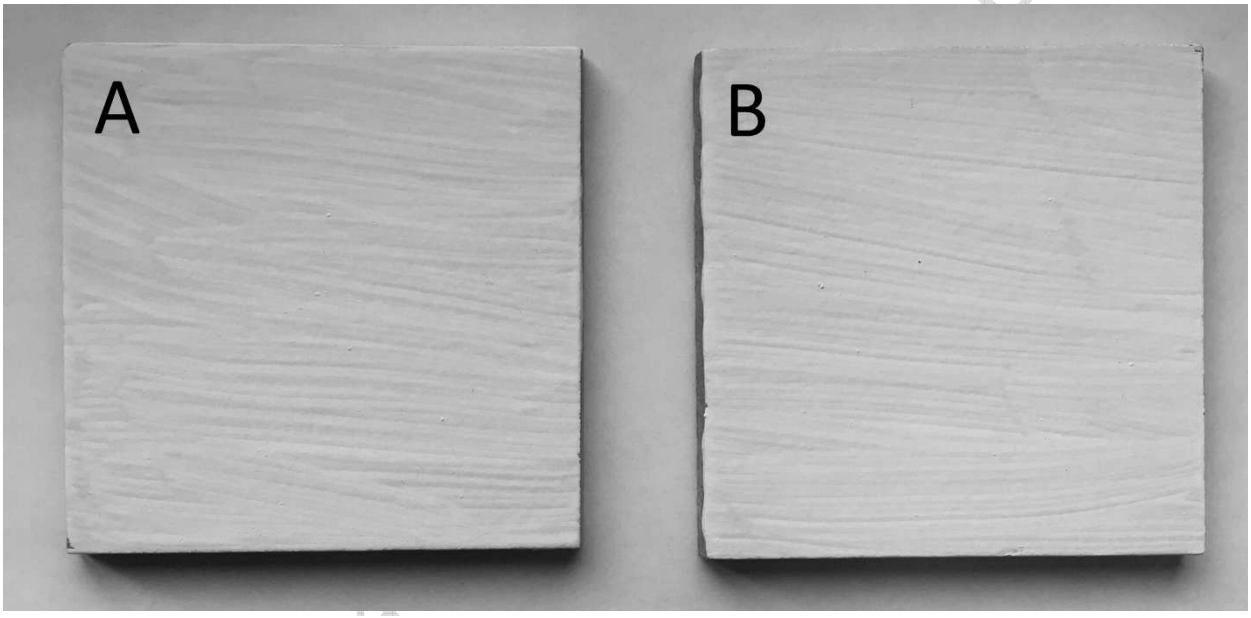

Figura 3. Pictures of the samples: A = BLG - UV, B = BLG - Vis. The sample face reported is the irradiated one (UV and Visible irradiation) during the photocatalytic NO / NO_x abatement tests.

3. EXPERIMENTAL RESULTS AND MEASURING CONDITIONS

3.1. *Sample "BLG – UV"*

The following table shows the operating conditions used in the test and its results.

Initial concentration of nitrogen oxides before entering the reactor	C_{NO}^{IN} = 0.512 ppmv $C_{NO_2}^{IN}$ = 0.000 ppmv
Gas flow	***F*** **= 1.608 dm^3 min^{-1}**
Temperature inside the reactor	***T*** **= 21.5 °C**
Relative humidity inside the reactor	***HR%*** **= 36.7**
Irradiance of the lamp to the sample surface (290-400 nm)	***I*** **= 10 W m^{-2}**
Time elapsed between the time the UV lamp is switched on and the start of the concentration recording	**34 min**
Conversion in the absence of sample	$C_{NO}^{OUT,BUIO}$ = 0.5036 ppmv $C_{NO_2}^{OUT,BUIO}$ = 0.016 ppmv $C_{NO}^{OUT,LUCE}$ = 0.4972 ppmv $\eta_{NO,lamp}^{foto}$ = 1.3 %
Conversion in the dark in the presence of a sample	η_{NO}^{buio} = 0.7 % $\eta_{NO_2}^{buio}$ = 0.7 %
Conversion under radiation in the presence of a sample	The graph showing the evolution of the concentrations during the various test steps is shown in Figure 4.
Observed rate of photocatalytic degradation	**see Table 2 2**

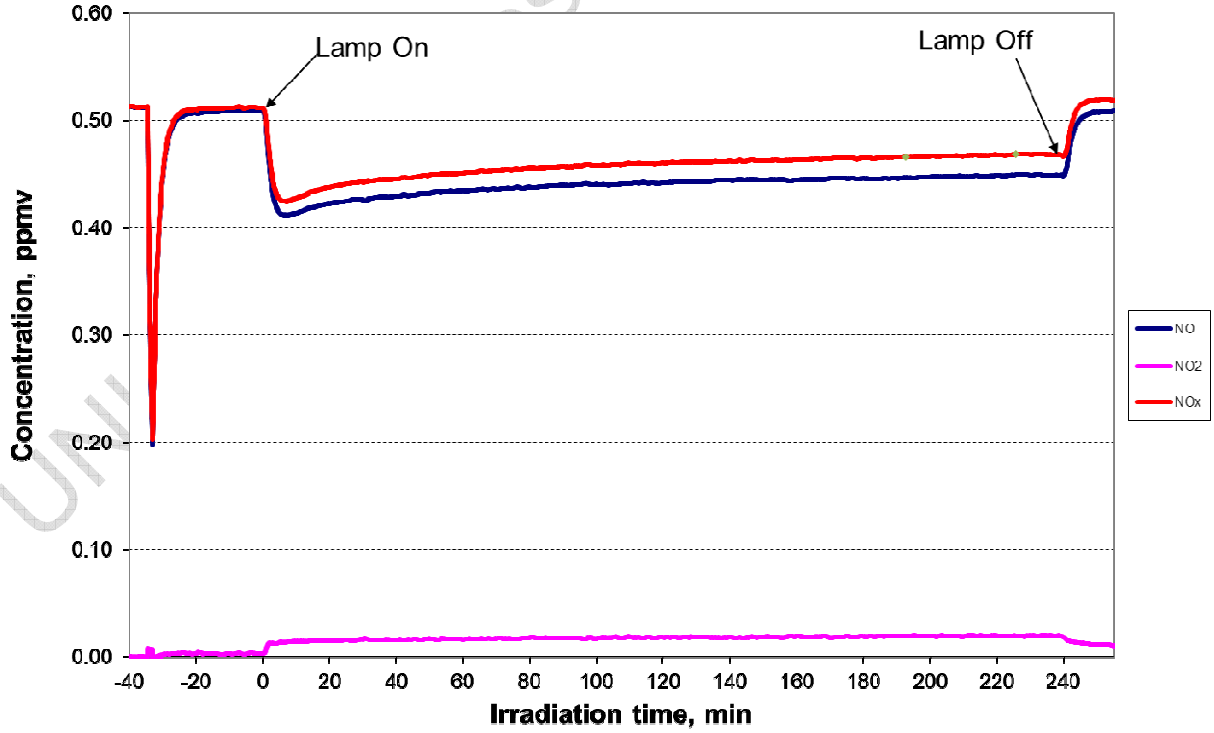

Figure 4. Concentration vs time for NO, NO_2 and NO_x during the photocatalytic test on BLG - UV sample. Test dated 20-12-2020 and performed with UV radiation in accordance with UNI 11484 (simplified).

3.2. Sample *"BLG – Vis"*

The following table shows the operating conditions used in the test and its results.

Initial concentration of nitrogen oxides before entering the reactor	C_{NO}^{IN} = 0.512 ppmv $C_{NO_2}^{IN}$ = 0.000 ppmv
Gas flow	***F*** = 1.608 dm^3 min^{-1}
Temperature inside the reactor	***T*** = 25.2 °C
Relative humidity inside the reactor	***HR%*** = 27.4
Irradiance of the lamp to the sample surface (290-400 nm)	***I*** = 250 W m^{-2}
Time elapsed between the time the UV lamp is switched on and the start of the concentration recording	30 min
Conversion in the absence of sample	$C_{NO}^{OUT,BUIO}$ = 0.5036 ppmv $C_{NO_2}^{OUT,BUIO}$ = 0.016 ppmv $C_{NO}^{OUT,LUCE}$ = 0.4972 ppmv $\eta_{NO,lamp}^{foto}$ = 1.3 %
Conversion in the dark in the presence of a sample	η_{NO}^{buio} = -0.2 % $\eta_{NO_2}^{buio}$ = 0.4 %
Conversion under radiation in the presence of a sample	The graph showing the evolution of the concentrations during the various test steps is shown in Figure 5.
Observed rate of photocatalytic degradation	see Table 2

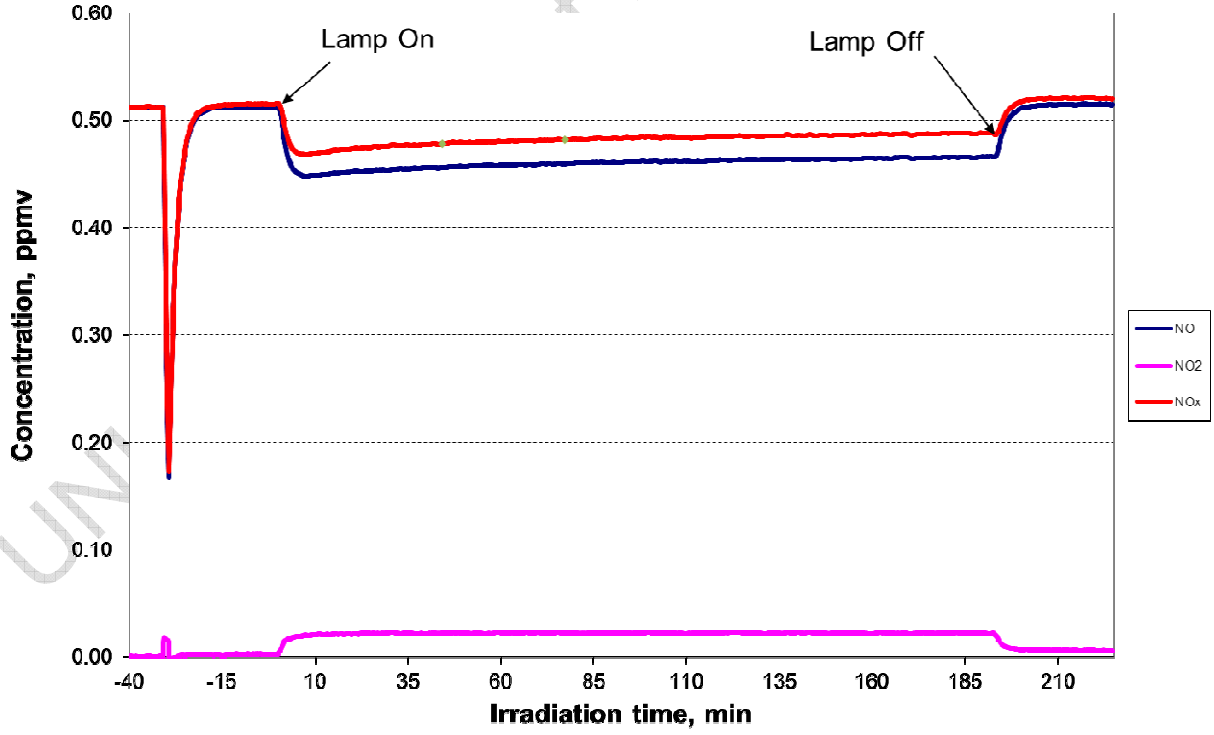

Figure 5. Concentration vs time for NO, NO_2 and NO_x during the photocatalytic test on BLG - Vis sample. Test dated 23-10-2019, and performed with visible irradiation notwithstanding the UNI 11484 (simplified) standard.

4. SUMMARY OF RESULTS

The results of measurements of the photocatalytic activity of the two samples are summarized in Table 2. The conversions and rates are given as average values calculated after 180 minutes of irradiation in accordance with the UNI 11484.

Table 2.. Measurement results. The conversions refer to the measured values after 180 minutes of irradiation.

Sample	**Irrradiation**	$\eta_{NO,i}^{totale}$ **, %**	$\eta_{NO_x,i}^{totale}$ **, %**	$r_{NO,i}^{foto}$ **,** **µg m^{-2} h^{-1}**	$r_{NO_x,i}^{foto}$ **,** **µg m^{-2} h^{-1} [*i*]**
BLG – UV	UV	10.3	6.9	810	930
BLG– Vis	Visibile	9.1	4.8	580	510

[*i*] The photocatalytic NO_x conversion rate is expressed as µg equivalents of NO_2 converted per m^2 of sample in 1 hour.

The analyzed samples show, both under UV irradiation and under visible irradiation, a measurable photocatalytic NO abatement in the test conditions equal to 810 µg m^{-2} h^{-1} under UV irradiation, and to 580 µg m^{-2} h^{-1} under visible radiation, respectively.

Torino, January 10, 2020

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