SELECTION OF COMMERCIAL PHOTOCATALYTIC MATERIALS BASED ON THEIR AIR-PURIFYING ABILITY

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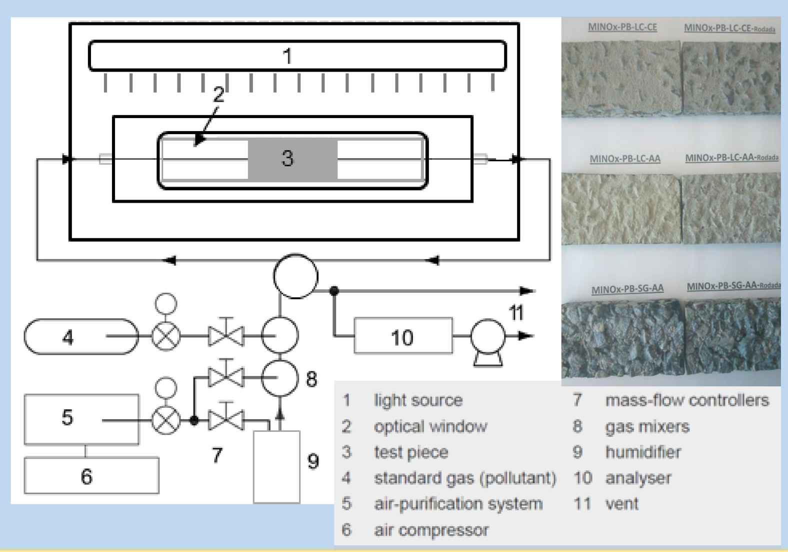
INTRODUCTION

One complementary emerging strategy that could help to mitigate air pollution at urban areas is the use of photocatalytic products which can be implemented on a vast variety of urban infrastructures. Photocatalytic TiO_2 materials are activated in the presence of sunlight and can remove, more specifically, nitrogen oxides (NO_x) from the ambient air via heterogeneous photocatalysis [1]. This option could be especially interesting for different European urban agglomerations, exceeding the limit values for NO_2 (Directive 2008/50/EC), like the case of Madrid city and the close municipalities. For these cities, applying TiO_2-modified cementitious materials onto the external covering of buildings or roads might be a supplement to conventional technologies such as catalytic converters fitted on the vehicles for reducing gaseous exhaust emissions.
In the framework of the European project LIFE MINO$_x$-STREET, co-financed by the EU, a variety of commercial photocatalytic materials has been tested under controlled conditions and the results used to compare the potential usefulness of them to act as NO_x sink and select, among them, the most promising solutions to be implemented on urban surfaces at real conditions. Further, NO_x deposition velocities, needed for modelers to evaluate the potential impact of their use at real urban scale have been estimated.

EXPERIMENTAL

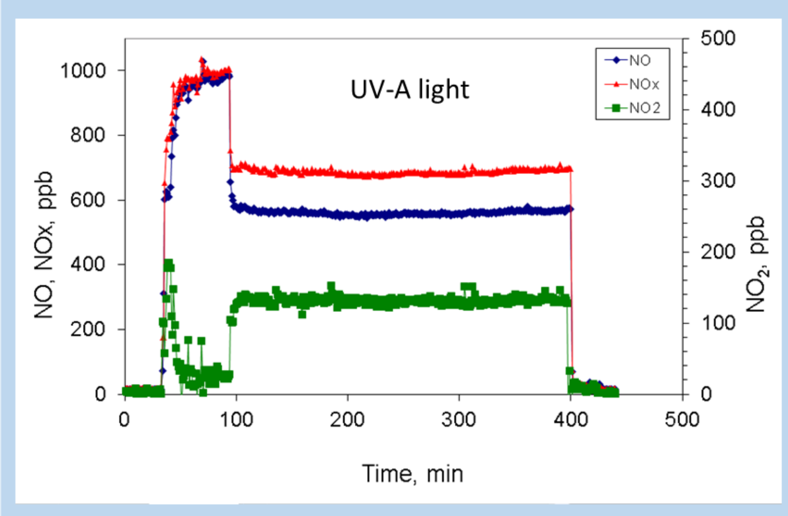
A strict essay protocol has been developed to test and compare the potential usefulness of a variety of commercial photocatalytic materials to act as NO_x sink when are implemented on urban surfaces at real conditions. Their photoactivation and air-purifying capacity under controlled conditions have been investigated and documented.

Some photocatalytic materials tested to prove their NO removal capacity



Scheme of the ISO 22197-1 test equipment and some photocatalytic concrete samples

The samples obtained were cut into 99 mm x 49 mm x 5 mm specimens. The photocatalytic activity of these photocatalytic concrete samples was then essayed under ISO 22197-1:2007 [2] by using a bed flow photo-reactor. A test gas mixture flow (NO, air, H_2O) (50% relative humidity) is passed over the rectangular sample and is irradiated by UV-A light (10 W m^{-2} irradiance) through a UV transparent window with a distance to the sample of 5 mm.



ISO 22197-1 test results for a photocatalytic material

Amount of NO removed from the test gas, n_{NO}*:*

$$n_{NO} = (f/22{,}4)\int(\varnothing_{NO_{in}} - \varnothing_{NO_{out}})dt$$

n_{NO} , amount of NO removed by the test piece (µmol)
f , air-flow rate converted into that at the standard state (0°C, 101.3 kPa, and dry gas basis) (l min^{-1})
$\varnothing_{NO_{in}}$, supply volume fraction of nitric oxide (µl l^{-1})
$\varnothing_{NO_{out}}$, nitric oxide volume fraction at the reactor exit (µl l^{-1})

Dimensionless measure of the NO abatement, χ*:*

$$\chi = \left(\frac{\varnothing_{NO_{in}} - \varnothing_{NO_{out}}}{\varnothing_{NO_{in}}}\right)\cdot 100$$

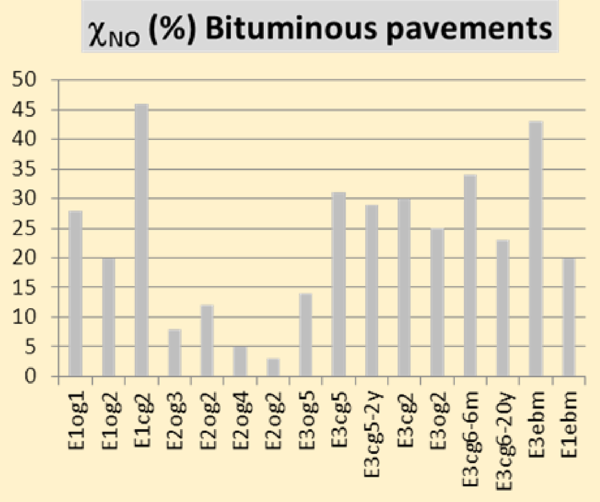
REFERENCES

[1] Finlayson-Pitts B.J., Wingen L.M., Sumner A.L., Syomin D. &, Ramazan K.A., *Phys. Chem. Chem. Phys.*, **6**, (2003) p. 223-242.
[2] International standard ISO 22197-1:2007, Geneve, 2007.

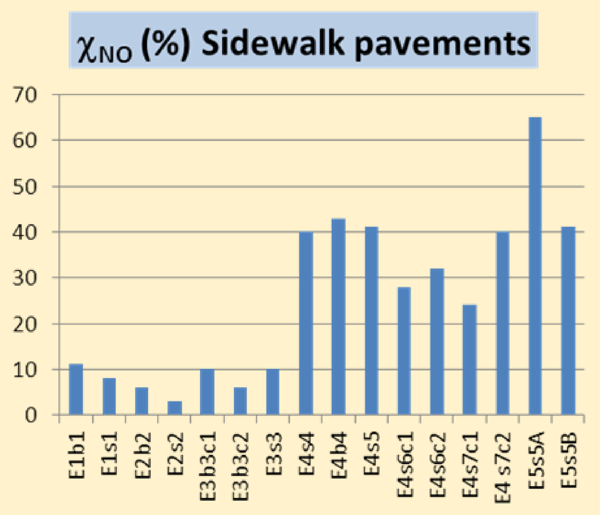
RESULTS AND DISCUSSION

NO removal efficiency for all photocatalytic materials tested

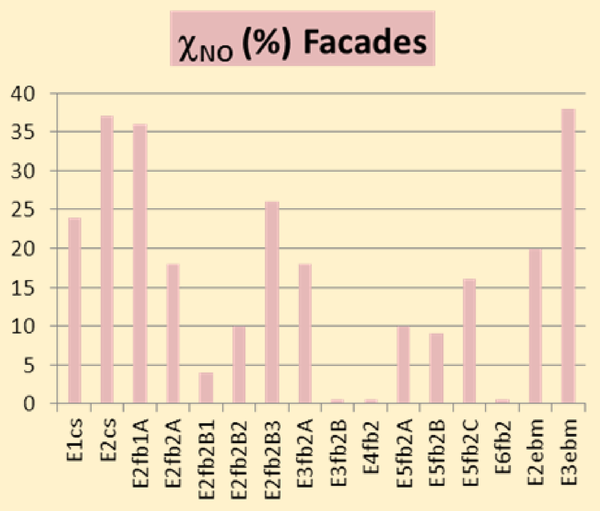
Bituminous concrete pavements:
- open graded or close graded +
  - photocatalytic mortar
  - photocatalytic water emulsion



Sidewalk concrete pavements:
- photocatalytic paving block
- photocatalytic paving slab
- paving block or paving slab +
  - photocatalytic sol-gel
  - photocatalytic water emulsion
  - photocatalytic coating



Facade:
- Concrete surface or face brick +
  - concretal lasur
  - photocatalytic paint
  - photocatalytic coating



Estimation of NO_x deposition velocities from laboratory data

From simple **NO differential mass balance**:

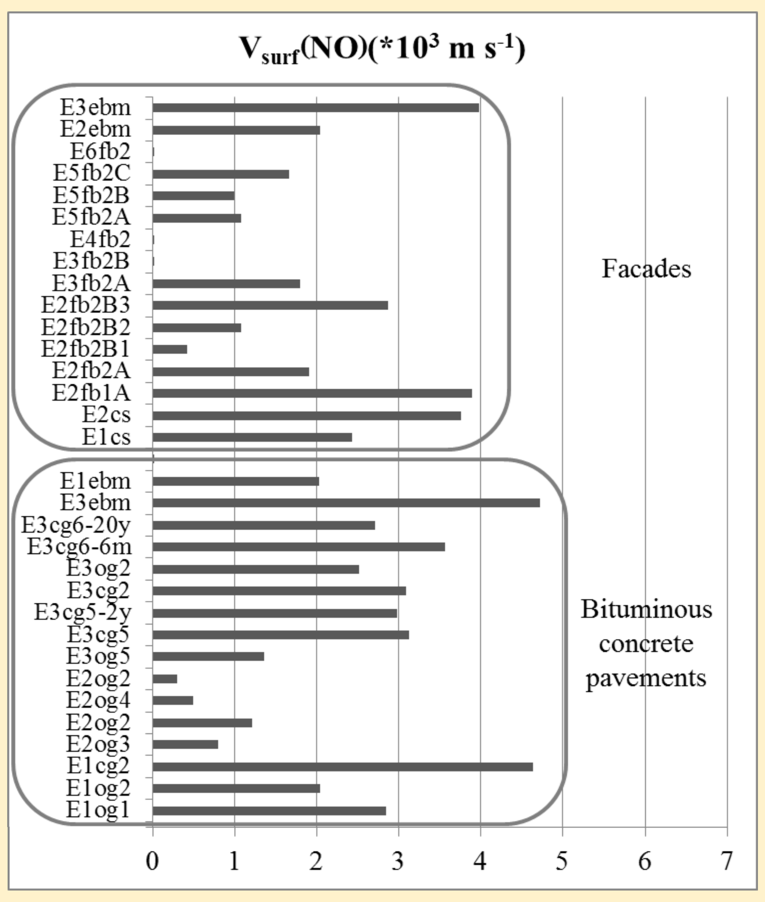
$$F_{surf} = \frac{f(\varnothing_{NO_{in}} - \varnothing_{NO_{out}})/22{,}4}{W \cdot L} M_{NO}$$

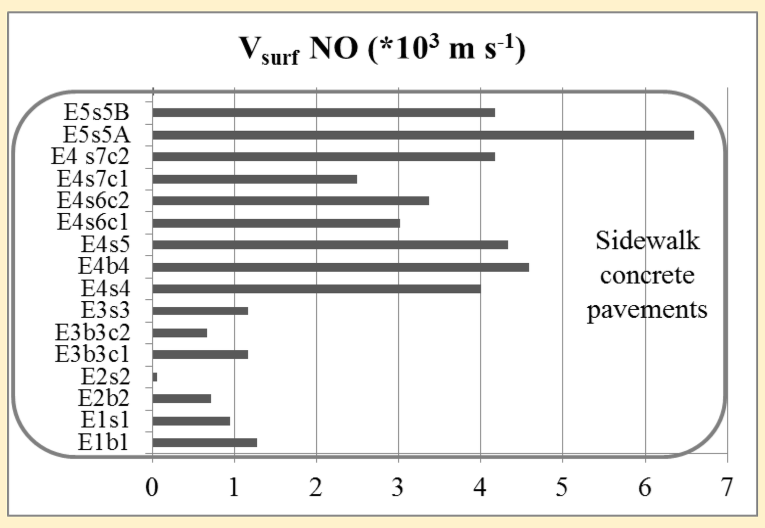
W , test piece width (m)
L , test piece length (m)
M_{NO} , molar mass of NO (g mol^{-1})
F_{surf} , NO flow at the surface (e.g. µg m^{-2} s^{-1})

a surface deposition velocity can be estimated:

$$V_{surf} = -\frac{F_{surf}}{C_{NO_{in}}}$$

V_{surf} is the deposition velocity (ms^{-1})
$C_{NO_{in}}$ is the NO mass concentration (µg m^{-3}) at the inlet





Not only the substrate and photocatalytic products but also the way of application of those products (spraying, rolling) can have a huge influence in the efficiency observed.

Taking the removed NO as starting point, it is possible to estimate an NO deposition velocity by using the NO mass removed. The surface deposition velocities, V_{surf}, computed by following a simple NO mass balance approximation, reflect the diverse NO purifying capability.

CONCLUSIONS

A comparative study on photocatalytic materials, available in the European market, was carried out in order to assess their efficiency. NO degradation was found to vary notably under optimum laboratory conditions. Some of them have demonstrated a substantial capacity to remove NO, potentially enough to observe NO sink effects in ambient air. Nevertheless, a proper selection of air-purifying products for projected applications at real scale is mandatory.
Additionally, experimental results of the ISO test can be used to compute an approximate NO surface deposition rate by using a simple mass balance. This deposition rate is dependent on both the geometry of the photo-reactor as the physical conditions in which the test is carried out. However, the methodology described can be useful to have an estimation close to the actual value of the NO deposition velocities magnitude of photocatalytic materials and their potential effect in outdoor conditions.

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