CENTRO DI RICERCA E SPERIMENTAZIONE
PER L'INDUSTRIA CERAMICA

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CERTIFICATE

Subject: Comparative study on the NO_2 removal capacity of trees and ceramic tiles from the Advance series

1. Introduction

As requested (ref. CONTR-V2025-0487), a literature review on the nitrogen oxides removal capacity of trees was carried out with the aim of comparing it to the photocatalytic performance of ceramic tiles from the Advance® series.

2. Methods

The literature review was mainly carried out through the international databases “Scopus” and “ScienceDirect”, coupled, when necessary, with researches on the main search engines.
The NO_2 removal capacity of the tiles from Advance Rondine 3D series was estimated from the test report of the Department of Chemistry of the University of Turin (08/06/2020) named: “Determination of the photocatalytic activity with the tangential flow method - reduction of nitric oxide (UNI 11484 simplified method, in accordance with CEN / TS 16980-1: 2016) on materials - Rondine ceramica, Advance Rondine Collections 3D series”. This test report shows that the NO_x photocatalytic conversion rate, expressed as µg of NO_x per m^2 of sample per hour, and determined according to the standard CEN/TS 16980-1:2016, is the following for the three different tiles examined:

- 1130 µg m^{-2} h^{-1}
- 1140 µg m^{-2} h^{-1}
- 1060 µg m^{-2} h^{-1}.

For this study, the average value was considered: 1110 µg m^{-2} h^{-1} (1.110 mg m^{-2} h^{-1}).

3. Results and Discussion

In the 1970s-1990s, several studies investigated the potential capacity of trees to absorb nitrogen oxide (NO_2) [1-3]. These studies examined the capacity of trees to use this gas as nitrogen source for their growth, if there are no other sources. In this way, trees could also contribute to reduce air pollution in urban and industrial areas. These experiments were mainly carried out by placing small plants in measuring cells, equipped with systems for the determination of the gaseous pollutant concentration over time [2]. According to the authors [2], the NO_2 absorption capability of some broad-leaved trees (including poplar, oleander, oak and viburnum) is between 0.1-0.3 mg dm^{-2} day^{-1}, corresponding to 0.4-1.2 mg m^{-2} h^{-1}, per unit of leaf area. Other authors [4] investigated the NO_2 absorption capability of several plant species (including ficus, ivy, dieffenbachia and hibiscus, i.e. essentially small potted plants), finding an average value of 22.3 µl dm^{-2} h^{-1}, corresponding to 4.2 mg m^{-2} h^{-1}, per unit leaf area.
As it is possible to notice, these values show significant inconsistency (they have different magnitudes). It is mainly due to the lack of uniformity between the different experimental methods, but it is also due to the fact that the nitrogen oxides absorption in plants, being a function of their living nature and stomata behaviour present on the surface of the leaves [4], is extremely variable. In fact, several literature reviews clearly show that the efficiency of the NO_2 removal capacity of trees strongly depends on several factors [5], including the plant species, the atmospheric conditions (e.g.,relative humidity and temperature) [6] and the presence of other pollutants in the air [1-2]. Furthermore, other authors show that the NO_2 absorption could damage the plants when other gaseous polluting agents are present in the atmosphere, such as ozone (O_3) [2] and sulphur oxide (SO_2) [1]. In addition, since the NO_2 removal capacity of broad-leaved trees is much bigger than that of conifers [6], it decreases during the leaf-shedding period.

In recent years, studies focused on a more realistic assessment of the NO_2 removal capacity of trees in several polluted urban regions, through a double approach.

Some researchers have statistically determined the NO_2 concentration in urban streets characterized by a consistent tree presence and others characterized by their complete absence. These studies state that the trees impact on the nitrogen oxides concentration can be considered negligible [7-9], even if the overall impact of trees in urban areas is however positive in terms, for example, of shading and cooling.

On the other hand, different studies considered larger green regions, such as the sum of all the tree-covered areas (parks and gardens) within whole cities or their portions. From these studies it was possible to identify more consistent data, summarized in the Table 1.
In particular, by taking into account the data of a study carried out in Strasbourg (Table 1), it is possible to conclude that the **NO_2 removal capacity of the surface of tiles from Advance series is 65 times higher than that of the total leaf area of trees** of the considered green regions.

Table 1. The results were obtained from 3 different studies focused on green areas in urban regions (n.d.=no data)

City	Tree species	NO_2 absorbance per leaf area (mg/m^2h)	Reference
Beijing (China)	Sofora, ash, poplar, juniper	0.107	[10]
Santiago (Chile)	n.d.	0.025 (area 1) 0.069 (area 2)	[11]
Strasbourg (France)	Beech, ash, maple	0.017	[12]

Starting from these values, the calculation of the number of equivalent trees is not straightforward, since the leaf area of each tree strongly depends on its species and age. In fact, the leaf area of a single tree is a not very significant parameter and for this reason it is not broadly used. Rather, LAI (Leaf Area Index) is usually used [13-14], because it represents the ratio of total leaf surface (meaning the surface area of one side of the leaves, that facing the sun) to the ground area it covers (the projection of the canopy on the ground). By taking into account, for example, an ash tree, which is one of the species examined in the study carried out in Strasbourg, its LAI value is 2.8, for a tree of 30 years old, considered full-grown [15]. It means that **100 m^2 of tiles from Advance series remove an amount of NO_2 from a polluting atmosphere which is equal to the amount absorbed by a tree-covered area of 2332 m^2** (intended as only the projection of the canopy on the ground, without any space between the different trees). By assuming a tree arrangement as shown in Figure 1, it results that **100 m^2 of tiles remove an amount of NO_2 equal to the amount absorbed by a tree-covered area of 2978 m^2**. It is a simplified model and, if a more realistic (lower) tree density was considered, the resulting equivalent tree-covered area would be much larger.

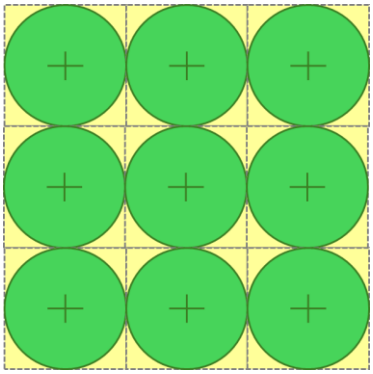

Figure 1. Tree distribution considered for the calculation of the equivalent tree-covered area, taking into account the extent of the canopy alone

4. Conclusions

The literature review and the analysis of the investigated data allow us to draw the following conclusions:

- Under controlled experimental conditions (small plants placed inside measuring cells in laboratories), trees show a certain nitrogen oxides removal capacity, but the obtained results are not consistent, due to the different set-up adopted during the

experiments and their wide broad values in input parameters. In fact, the capacity of trees and plants to absorb nitrogen oxides largely varies according to the plant species (for example the absorption capacity of broad-leaved trees is bigger than that of conifers) and to the external environmental conditions. Furthermore, the absorption capacity is almost zero during the absence of leaves, so for many months per year;

- In the presence of other gaseous pollutants, such as ozone and sulphur oxides, which are very common in urban and industrial regions, the NO_2 absorption could cause biological damage to the trees;
- Experimental studies carried out on tree-lined avenues in several cities show that the impact of trees in the reduction of NO_2 concentration can be neglected, even if trees however play an important role in the general well-being of citizens (e.g., shading and cooling);
- Studies carried out at the urban scale in China, Chile and France allow to estimate the NO_2 removal capability of trees. Taking the European study as reference, that capability, relative to leaf area and time, is 0.017 mg m^{-2} h^{-1}. This means that **the NO_2 removal capacity of tiles from Advance series is 65 times higher than the leaf area of the trees taken into account (Figure 2).**
- Calculation based on literature data for ash trees show that **100 m^2 of tiles from Advance series can remove an amount of NO_2 equal to 2332 m^2 of tree cover, which correspond to almost 3000 m^2 of land, in the configuration when tree canopies meet each other (Figure 3).**

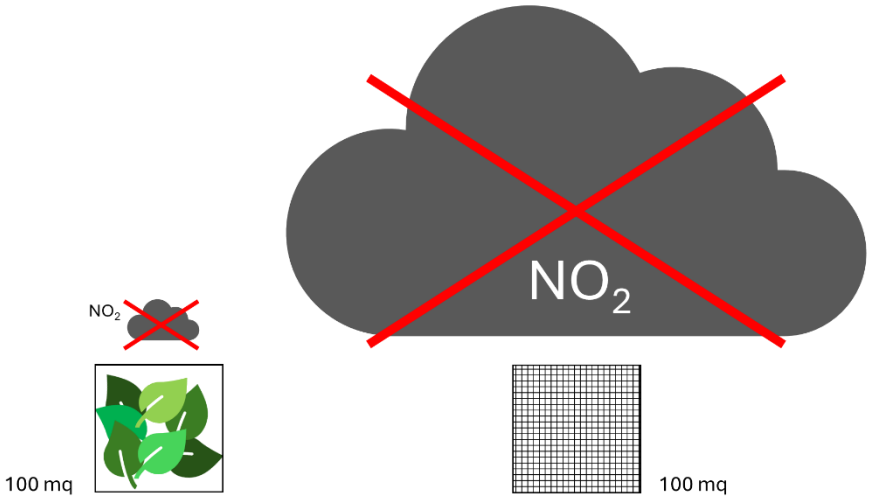

Figure 2. Equivalence between the NO_2 reduced by the same surface area of ADVANCE tiles and leaves, under the conditions previously described.

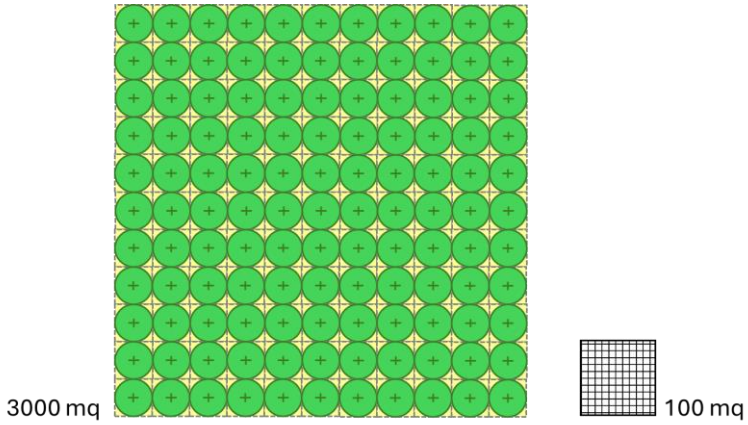

Figure 3. Equivalence between the surface area of ADVANCE tiles and that of wooded land which are able to reduce the same amount of NO_2, under the conditions previously described.

That study shows that **the pollutants (NO_2) removal capacity of tiles from ADVANCE Rondine series:**

- **Is more than an order of magnitude higher than the removal capacity of trees;**
- Provides **more consistent and less variable results than trees, which not only lose their leaves for several months per year, effectively reducing to zero the NO_2 absorption, but can also suffer from biological damage** caused by the pollutants removal.

Riferimenti

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