CSAP REVIEW OF A STUDY ON THE REDUCTION OF NO AND NO_2 CONCENTRATIONS IN THE AIR BY USING PROTECTAM FN® PHOTOCATALYTIC COATINGS, INCLUDING A METHODOLOGY AND RECOMMENDATIONS FOR DETERMINING THE EFFECTIVENESS OF PHOTOCATALYTIC COATINGS

INTRODUCTION:

A study by the Czech Republic's Institute of Physical Chemistry (IPC) examined the process of removing NOx from ambient air using the Protectam FN® photocatalytic coatings that are developed, patented and produced by the company Advanced Materials-JTJ, s.r.o. Choice of methodology was made in accordance with the applicable ISO standard 22197-1 and a proposed CEN standard. The study modified these standards in order better approximate real conditions. It answered the basic question of whether this photocatalytic technology is useful in reducing NOx pollutants (NO+NO2) in the air.

The study answered a number of outstanding questions:

1) The impact of NOx pollutant reduction on the effectiveness of the photocatalytic technology.
2) The impact of laminar and turbulent air flow on the effectiveness of the decontamination process.
3) The effectiveness of the photocatalytic surfaces in experiments lasting considerably longer that is prescribed by the aforementioned standards.
4) The effectiveness of the photocatalytic surfaces in the reduction of NO2 in the air. No norm has yet been specified for this type of experiment.
5) The impact of adsorption and desorption of nitrogen oxides by the photocatalytic surface.
6) The impact of application on conventional substrates (concrete, plaster), compared to application of the layers on glass, where the glass substrate cannot positively or negatively influence the photocatalytic reaction (the photocatalytic layer was tested only at laboratory temperature).
7) The impact of layer thickness on the effectiveness of the photocatalytic process.
8) Comparison of Protectam FN® products with a pure nano-TiO2 photocatalyst (Aeroxide TiO2 P25), which has very high photocatalytic effectiveness and is recognized as an industry standard.
9) Assessment of the final products of photocatalytic oxidation captured on the photocatalytic surface of the sample.

SUMMARY

The study answers the aforementioned questions as follows:

Ad 1) The photocatalytically treated surface is able to remove 20-50% of nitrogen oxides upon contact with contaminated air at low concentrations of NO that correspond to the actual pollutant situation in city air, under conditions that approximately correspond to those prescribed by the ISO test.

Ad 2) The influence of the type of air flow on the effectiveness of the photocatalytic technology is not significant. The achieved efficiency of a photocatalytic layer on concrete for nitrogen oxides removal from the air is almost the same under all conditions, (removal of 0.04 ppm, i.e. a 40% decrease in NOx, given an input concentration of 0.1 ppm of NO).

Ad 3) The study showed that prolonged exposure leads to a steady state after approximately 20 hours, therefore photocatalytic activity was not evaluated at the the initial high level but only after a long-term steady state was achieved, i.e. in a range of 15-25 hours.

Ad 4) Experiments with nitrogen oxide (NO2) showed that using photocatalysis it is possible to achieve a significant decrease in its concentration (typically by 0.04 ppm with an initial concentration of 0.1 ppm, i.e. 40%) and that the humidity of the air is very important (at 100% relative humidity the decrease in concentration is greater than at 50% relative humidity).

Ad 5) The tests proved that the removal of nitrogen oxides on the examined surfaces is due exclusively to the photocatalyst, not to adsorption into the surface.

Ad 6) Subsequent measurements of the photocatalytic layers on various substrates show that the impact of the type of substrate on the photocatalytic process is not very significant but that substrate thickness plays an important role.

Ad 7) The thickness of the photocatalytic layer has an impact on photocatalytic activity. Application in three layers, as recommended by the manufacturer (resulting in a layer of approximately 20 micrometers) represents a reasonable compromise between high effectiveness and cost.

Ad 8) Comparison of Protectam FN® products and the pure photocatalyst Aeroxide Ti02 P25 shows that the Protectam products have very high effectiveness. The most positive aspect of Protectam FN® is the morphology and openness of the applied layer.

Ad 9) An independent study shows that NO oxidation decontaminates the air and that the final by-product remaining on a photocatalytic surface is nitric acid, which is subsequently neutralized by natural processes.

CONCLUSION

The photocatalytic technology used in Protectam FN® products can be an effective means of decontaminating ambient air of NOx pollutants. Studies and observations by the Czech Republic's University of Chemical Technology (UCT) and the manufacturer (see appendices) show that the photocatalytic surface of Protectam FN® can also be used for removal of volatile organic compounds (VOC) and preventing an increase in ground-level ozone concentrations in the air.

Thus, these surfaces may well contribute to an overall improvement of the air in exposed locations.

RECOMMENDATION

Choice of methodology for calculation of the effect of the photocatalytic technology used in Protectam FN® on decontamination of the air in a specific location.

The studies introduce the term "DeNOx factor", which expresses the percentage reduction of nitrogen oxides concentrations at the point of contact with a photocatalytic surface.

To calculate the air decontamination effect, we start with the following values:

1) the average concentration of NOx in mg/m3 of air [C],
2) the average speed of airflow in the specified location (v),
3) the overall area of the photocatalytic surface (S).
4) Average DeNOX factor determined by measurements of the stabilized state (DeNOX).
5) Time of exposure (t - in seconds, given 8 hours per day of exposure).
6) The air flow rate in 1 m/s (0.7).

The statistical average intensity of solar radiation, that is, 10% of the maximum intensity of solar radiation under our conditions, is expected.

Calculation: How much NOx is in the particular photocatalytic area of 654 m2 (in the attached figure) that has to be removed from the air per year?

Costs of the application - model example 654 m2

X= 0.7*v*[C]*S*t* DeNOx

decrease of NOx per year at v=2 m/s, NO concentration 0.04 mg/m3 (the limit of concentration according to the Czech Hydrometeorological Institute), S=654 m2 and time 1 year = 31,536,000 s (if the exposure time is 8 hours per day - this corresponds to 10,512,000 s) and the DeNOx factor = 0.4 (40%)

X= 0.7*2*0.04*654*10,512,000*0.4 = 154,000,000 mg NOx

= 154 kg NOx/year.

The quantitative extrapolation based on laboratory measurements of the photocatalytic decontamination effectiveness on ambient air shows that the amount of nitrogen oxides removed can be substantial (the corresponding quantity of HNO_3 produced as a by-product is 211 kg per year). Therefore it is also necessary to take into account disposing of a substantial quantity of nitric acid deposits, e.g. by periodic rinsing with water. The nitric acid is gradually and naturally flushed away by rain, but there is the possibility of including flushing in the maintenance of facades in combination with suitable neutralization of the nitric acid, e.g. using diluted lime water. This would ensure an excellent ecological cycle of pollutant removal.

The cost of preparation of the photocatalytic layer specified by the manufacturer is 300 CZK/m2 (approximately 12 USD/m2 at current exchange rates), which corresponds to a cost of treating a model house of 200,000 CZK (approximately 8200 USD), i.e. with the product's guaranteed lifetime of 10 years, 20,000 CZK (820 USD)/year. Another positive aspect of the façade treatment is the improvement in appearance thanks to the self-cleaning effect.

The quantity of air cleaned (of 40% of NOx) would be 10 billion m3 per year given the parameters used above in estimating the quantity of NOx removed. In view of the large volume of air cleaned the aforementioned costs are very low.

When determining the total cost it is necessary to take into account rinsing and neutralization of by-products. However without rinsing the façade the cleaning of 1 m3 costs only 0.00002 CZK (less than 1/1000 of a US cent).

Note: We recommend being careful with extrapolations in practice and solving for each case individually. The figures given are only a rough guide with a probability deviation of up to +/- 20%.

Based on the conclusions of the study we recommend using the Protectam FN® photocatalytic technology to decrease the concentration of NOx pollutants and other pollutants in exposed locations.

We recommend using this technology primarily in areas of high pollution.

The Protectam FN® technology can also be used as a measure to offset the impact of construction on the environment, as in a recent project for finishing of an administration building on Kováků street.

For other issues relating to the application of the photocatalytic coating we recommend following the manufacturer's instructions for use.

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