# Established and Novel Methods to decrease Urban Air Pollutants

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## Introduction

Emission control at source has been implemented in developed regions such as Europe and North America for more than 30 years. The more and more stringent regulation demonstrated noticeable effects on air pollutant levels. However, recent data show that this process has yet to meet all the expectations required by authorities and the World Health Organization (WHO) in term of air pollutant levels in urban areas.

Developing countries and specifically Asian countries are now engaged in the implementation of emission control regulations for both stationary and mobile sources. The challenge faced by these fast growing economies is actually bigger than in Europe or in North America as levels of air pollutants increase rapidly. Therefore, it can be predicted that emission control at source will take more time to have some significant and beneficial impacts on urban air quality.

Based on the experience gained over the last decade in the treatment of air pollutants at source, other solutions need now to be deployed. Emission control at source can also be complemented by the use of innovative proven technologies such as building materials actively depolluting the air. These novel solutions are particularly attractive to the fast-growing Asian region as they can offer a cost effective and efficient way to combat the air quality issues.

In this paper, we will discuss the emission control at source and some of its limitations in regions like Europe. We will present the other ways urban areas can accelerate air pollutant reduction and will focus on the results obtained with the latest depolluting building materials.

**The persistence of hazardous Air Pollutants levels**

Major air pollutants include Particulate Matter (PM), Oxides of Nitrogen (NOx) and Sulfur (SOx), Volatile Organics (VOCs) and Ozone ($O_3$). Today, PM, NOx, and Ozone are the most persistent and hazardous pollutants in our major urban areas.

NOx is formed during the combustion of fossil fuels like coal and gas when harmless oxygen and nitrogen gases combine to form oxides of nitrogen such as nitrogen oxide (NO), nitrogen dioxide ($NO_2$), and nitrous oxide ($N_2O$). These gases can cause respiratory problems; they also contribute to ground level smog, ozone formation and acid rain. Nitrous oxide is also a potent greenhouse gas.

NOx levels are dangerous to human health at the level of 200 $\mu g/m^3$ an hour. Nitrogen dioxide can cause a range of harmful effects on the lungs, including increased inflammation of the airways, worsened cough and wheezing, reduced lung function, increased asthma attacks, greater likelihood of emergency department and hospital admissions and increased susceptibility to respiratory infection, such as influenza (Source: *American Lung Association).* However, the exact impact on an individual will depend on the length and level of exposure to NOx, as well as the individual's health profile and stamina.

Developing countries tend to be exposed to higher levels of air pollution that the developed world. The World Health Organization (WHO) reports that the level of air pollution in downtown Cairo is 10-100 times what is considered a safe limit. Cairo is in the company of other cities like Mexico City, Bangkok, Saõ Paulo, Delhi, and Tokyo which are among the worst cities in the world in terms of air pollution. In 2010, across the city of Beirut, the average concentration of nitrogen dioxide was 58 $\mu g/m^3$ of air. This exceeds the maximum average concentration recommended by the WHO: 40 $\mu g/m^3$.

Urban outdoor air pollution is estimated to cause 1.3 million deaths worldwide per year from respiratory illnesses related to high levels of NOx and VOC pollution (Source: *Word Health Organization, Sept 2011*).

Both national and supranational authorities, such as the European Commission, are aware of the danger of NOx, and have attempted to deal with the problem through legislation.

**NOx abatement: the European Union case**

For nearly 30 years, catalysts have been used in systems to control air pollution 'at source'; with those targeting NOx based primarily on existing $TiO_2$ (Titania) solutions. The approach for solving the problem has been to deal with the primary pollutants at their source to prevent un-combusted or partially oxidized hydrocarbons and carbon monoxide from entering the environment by catalytically oxidizing them and catalytically reducing these to small amounts of water, carbon dioxide and nitrogen.

In power plants, for example, CristalACTiV™ ultrafine $TiO_2$ powders have been used in several different catalytic preparations, including extruded, coated and granulated forms. Since the 1990s, new $TiO_2$-based products have been developed to reduce NOx emissions from vehicles to meet stringent emissions regulations. These products are now widely used in the automotive industry around the world. NOx reductions as high as 90% are possible though deploying catalysts at source.

However, the current legislation has not been effective enough. For example, Nitrogen Oxide emissions still a major problem in Europe, despite the emissions ceilings set for each country by the European Commission in 2011 under Directive 2001/81/EC that was supposed to be achieved by 2010 (Source: *European Environmental Agency*). Nitrogen oxide ($NO_x$) limits were exceeded most frequently, with 12 Member States failing to keep emissions below agreed ceilings.

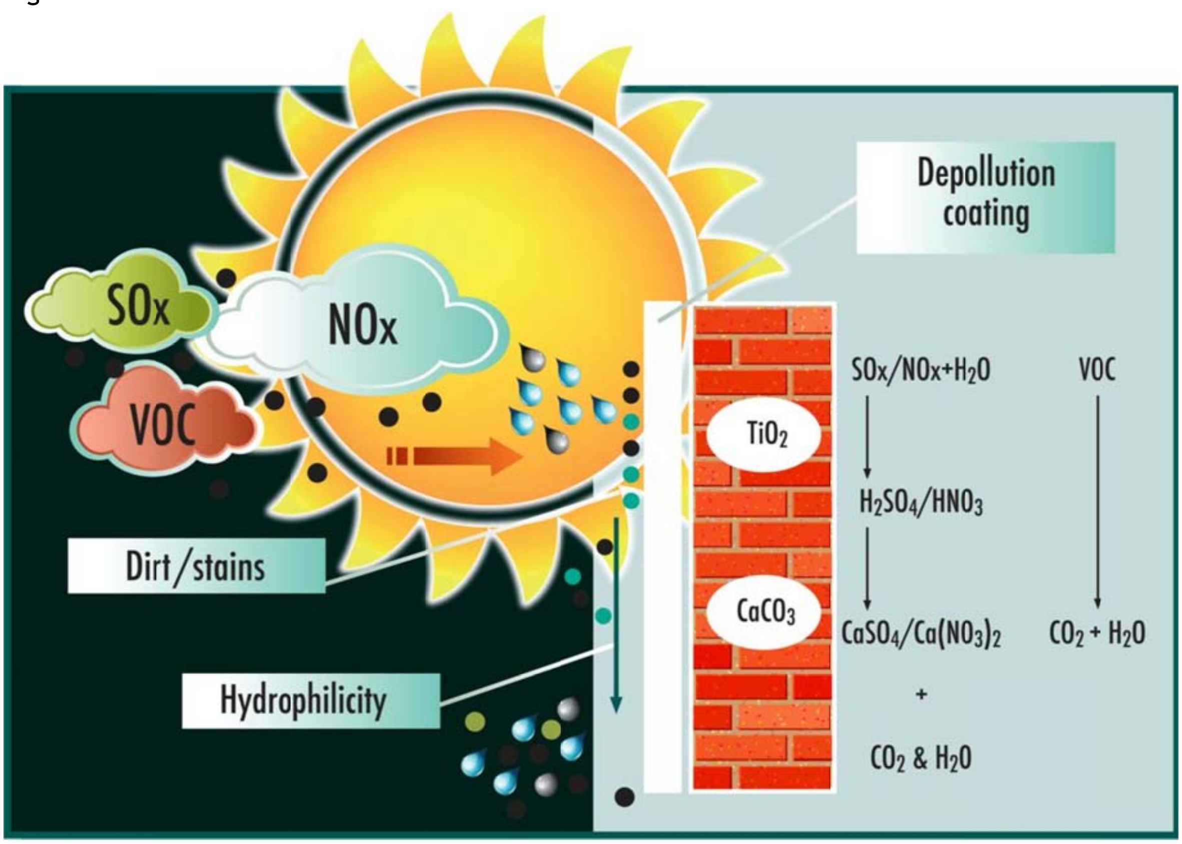
The problem of air pollution is likely to continue to grow due to the sheer numbers of sources that exist. The reality is that with greater industrial growth, and for instance more vehicles on the road, there needs to be investment in more novel and active chemical solutions. There is no easy solution to the problem even as work continues to develop better technologies to remove pollution at the source.

What is the solution for developing countries?

While controls at source are the primary form of pollution control, they are not the complete solution as the European Union case demonstrates. More needs to be done to deal with air pollutants that have either escaped from cars or power plants, or are formed via combustion reactions in the atmosphere. Based on the experience gained in pollution control at source, CristalACTiV™ photocatalytic products have been developed and can now be added to paint, coatings or building materials such as concrete, glass and steel to diminish the level or air pollutants in situ.

**The $TiO_2$ Photocatalysis technology**

Figure 1




A photocatalyst is a semiconducting material that can capture and absorb light, and use this energy to produce reactive chemical substances to increase the rate of a reaction. In the presence of UV light, the semiconductor $TiO_2$ reacts with water adsorbed onto its surface from the atmosphere, generating reactive hydroxyl radicals. These radicals can oxidize pollutant molecules, such as NOx, SOx and volatile organic compounds (VOCs) in close proximity to the catalytic surface, rendering them harmless. As a catalyst, $TiO_2$ is not consumed in the reaction so the reaction has a very long lifetime -- up to 15 years depending on the specific application.

Figure 1 shows how this technology breaks down pollutants NOx, SOx and VOCs into harmless products, such as water and harmless molecules of carbon dioxide. In the case of NOx, nitrates are formed; sulfates are formed from SOx, and carbon dioxide and water are formed when VOCs and any organic matter are oxidized. And since artificial and reflected light can also drive the catalytic reaction, the technology could be used in car parks and road tunnels that have inherent exposure to air pollution.

## Properly formulated Photocatalytic Materials are efficient

The potential of this technology to improve air quality in cities is immense. Field trials, using latest CristalACTiV™ photocatalysts for example, reveal reductions in NO as high as 60% and 20% in $NO_2$ in the immediate vicinity of the treated surface. If such technology were applied to buildings, surfaces in homes, schools and hospitals, and roads and pavements in cities, more pollutants could be converted to harmless products, generating cleaner air.

A trial in London ran for several years in the London borough of Camden and was able to scientifically demonstrate the photocatalytic action of $TiO_2$ and the reductions in NOx that CristalACTiV™ produced.

A photocatalytic CristalACTiV™ colloid was applied on a surface area of 135$m^2$ to see the impact on NO, $NO_2$ and NOx. The wall, treated with CristalACTiV™, was situated 25m from the roadside and was continuously monitored with data taken for 18 months. There were recordings taken of wind speed, direction, temperature and humidity. The trial shows the capacity of the photocatalytic material to remove up to 0.5g/$m^2$/day of NOx. This means that a surface of 300$m^2$ coated with this transparent colloid material can offset the NOx emission of 50 cars (Euro 4 standard) travelling 20 km per day.

A laboratory test confirmed the depolluting activity observed at Camden. In a Continuously Stirred Tank Reactor (CSTR), a 100 $cm^2$ test piece of concrete which had the CristalACTiV™ colloid applied at a loading of 12 g/$m^2$ $TiO_2$, has shown a rate of NOx removal of ~1 mg/m2/hr (test conditions were 100 ppbv NOx, 2l/min, 50 %RH, 20W/m2 UVA).

Photocatalysis materials are now proposed by several companies and properly formulated materials have demonstrated their depolluting properties in several architectural applications. One of the most significant demonstrations was a trial conducted by Pacific Paints (Boysen) in Manila, which coated selected areas of the MRT Guadalupe rail station. The trial on a surface of 4,100$m^2$ included a consultant who specialized in pollution monitoring and demonstrated the ability of the material to remove more than 100g of NOx per $m^2$ per year.

## A real opportunity for Asian developing economies

Air pollution levels must be addressed by multiple stakeholders, including businesses, local authorities, as well as individuals. Everyone has a stake in improving air quality and needs to play a part to de-pollute the air in major cities. Asian economies can go further than to just replicate the historical air pollution fighting model. There is no doubt that emission control at source is a must and best technologies are proven and available. However, actual and recent data shows that even emission control at source is not able to meet all the pollution ceilings expected in mature economies. A technology such as photocatalysis is available to complement the emission control at source. Photocatalysis is a cost-effective and immediate effect technology to reduce air pollution in non-attainment areas.