Chapter 64
An Innovative Air Purification Method and Neural Network Algorithm Applied to Urban Streets

Meryeme Boumahdi
University Abdelmalek Essaadi, Tétouan, Morocco

Chaker El Amrani
University Abdelmalek Essaadi, Tétouan, Morocco

Siegfried Denys
University of Antwerp, Research Group Sustainable Energy, Air and Water Technology, Antwerp, Belgium

ABSTRACT

In the present work, multiphysics modeling was used to investigate the feasibility of a photocatalysis-based outdoor air purifying solution that could be used in high polluted streets, especially street canyons. The article focuses on the use of a semi-active photocatalysis in the surfaces of the street as a solution to remove anthropogenic pollutants from the air. The solution is based on lamellae arranged horizontally on the wall of the street, coated with a photocatalyst (TiO_2), lightened with UV light, with a dimension of 8 cm × 48 cm × 1 m. Fans were used in the system to create airflow. A high purification percentage was obtained. An artificial neural network (ANN) was used to predict the optimal purification method based on previous simulations, to design purification strategies considering the energy cost. The ANN was used to forecast the amount of purified with a feed-forward neural network and a backpropagation algorithm to train the model.

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INTRODUCTION

Most cities in the world suffer from air pollution, due several many factors such as burning fuel, industry and release of chemicals (Kurt, 2016, Li, 2012, Li, 2017). Many studies have focused on reducing emissions of pollutants, with significant progress being made. So far, large part of the population in urban areas breathe air, that does not meet European standards nor the World Health Organisation Air Quality Guidelines (Kelly, 2015). Currently, there is no ready-to-use technology available for a sustainable removal of particulate matter (PM), Nitric Oxides (NOx), nor volatile organic compounds (VOCs), in an urban environment. The photocatalytic oxidation (PCO) has been the focus of increasing attention in recent years, to abate pollutants, with possible applications in several areas, including environmental and energy related areas. The Titanium dioxide (TiO_2) used as photocatalysts, is almost the only material suitable in industry at present and also probably in the future (Paz, 2010; Mamaghani, 2017). The choice of TiO2 is based on the highest stability, low cost, and transparency to visible light and a highly efficient photoactivity (Ribeiro, 2013). PCO is particularly useful for volatile organic compounds (VOC's), but according to the literature, the NOx can also be degraded to a lesser extent (to nitrogen). Furthermore, TiO_2 is also known to degrade the organic fraction of particulate matter (black carbon, soot). The latter is proven by many papers evidencing the self-cleaning properties of TiO2 (Bianchi, 2015).

In the last decades, thanks to advances made in computational resources, numerical simulation approaches have become increasingly popular. Nowadays, simulations with Computational Fluid Dynamics (CFD) is frequently used to assess urban microclimate.

Several research in artificial neural networks (ANNs) show that ANNs have powerful pattern classification and pattern recognition capabilities and they are used in many fields. They have become well established as viable, multipurpose, robust computational methodologies with solid theoretic support and with strong potential to be effective in any discipline (Dayhoff, 2001). Inspired by the biological system, especially the sophisticated functionality of human brains where hundreds of billions of interconnected neurons process information in parallel (Wang, 2003). ANNs algorithms are able to learn and generalize from examples and experiences as they have the ability to capture functional relationships among the data, even if the relationships are hard to describe or they are unknown. The advantage of using ANNs is that they minimize the error compared to other forecasting methods, and they provide results that are approximately close to analytical values.

Recent studies focusing on outdoor pollution show that the most important problem in the urban environment is the lack of urban ventilation. In this context, the proposed solution in this work focuses on the improvement of the contact with photocatalytic surfaces, taking advantage from the self-cleaning properties of TiO_2. In this paper, a new solution for outdoor air purification based on semi-active photocatalysis is described. We present an innovative solution for outdoor air purification, using photocatalysis technology. This technology is based on coated lamellas with TiO_2, lighted with UV light and placed horizontally on the buildings, in streets, using forced convection with a fan to force polluted air over the system. Natural convection was tested to in order to reduce the energy cost. It replaces the airflow generated by the fans, with an airflow produced by the density difference of the air between the lamellas. Considering the complexity of the interactions involved, a modelling approach is the designated approach to follow. In the present work, air flow, adsorption / desorption and photocatalytic reactions were studied using commercial computational fluid dynamics (CFD) software (Table 1).

The first section of the paper provides a literature review and related work on photocatalysis properties and its use on air purification. The multiphysics modeling section explains in detail the use of CFD and