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Filling station short-range impact on the surrounding area: A novel methodology for environmental monitoring based on the shadows study

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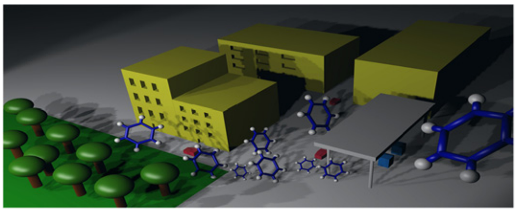
HIGHLIGHTS

- A novel strategy is illustrated to evaluate the polluting impact of a filling station on the surrounding area.
- A machine learning algorithm was trained to predict the wind field of the area under investigation by using the shadowing effect of obstacles and anemometric conditions.
- The numerical resolution of the Advection–Dispersion equation was used to calculate in real time the concentration of pollutants.
- The analytical detection of the pollutant concentration in the air of the area under investigation confirmed the accuracy of the proposed strategy.

GRAPHICAL ABSTRACT



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ABSTRACT

We studied the polluting impact of a filling station on the surrounding area by means of a novel approach. Given the fact that a precise relation can be found between the influence of a physic obstacle on the dispersion of gaseous substances and the "shadow" effect of the same obstacle (i.e. the shielding of a light source), we collected data about the shadowing effect of any kind of obstacle present in an urban area (e.g. buildings, trees, etc.). A machine learning algorithm was trained with the collected data in combination with historic anemometric conditions to predict the wind field of the area under investigation without prior acquiring detailed information about the presence of buildings, obstacles, trees, overpasses, etc. We used the numerical resolution of the Advection–Dispersion equation to calculate in real time the concentration of pollutants. The analytical detection

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Neural network
Pollution dispersion modelling

of the pollutant concentration in the air of the area under investigation confirmed the accuracy of our strategy. These unique results demonstrate that our original approach can be a very promising technique for short-range environmental studies inside complex area.

1. Introduction

Industrialisation and urbanisation contributed to the increasing of air pollution. In urban areas the main source of polluting Volatile Organic Compounds (VOCs) is usually traffic. Furthermore, filling stations located within the cities contribute significantly to the contamination of the air that we breathe. VOCs in the surrounding areas can originate from oil stations that deliver fuels, petroleum storage and other oil operations (loading, unloading and transportation). Leaks or emissions, coming from the fuel transfer, contribute to the local ambient contamination by releasing VOCs. Several recent studies have been performed in order to investigate the effect of filling stations on the workers and nearest living people. Sehgal et al. monitored petroleum-filling stations to assess variations in VOCs content (Sehgal et al., 2011). They settled that it is necessary to safeguard the health of the workers through the redesign of fuel stations. Morales Terrés et al. developed a novel methodology to establish a ''belt'' around petrol stations where vulnerable populations and activities, such as schools and hospitals, should be restricted (Terres et al., 2010).

The investigation of air safety involves a combination of chemical data inventory and aerodynamic information about the location of interest. Since the transportation of chemicals is mainly due to the wind, a detailed wind field analysis is needed to perform dispersion modelling. In the specific case of pollutant dispersion modelling inside a city district, a short-range modelling capability is required. Correa et al. performed Gaussian plume dispersion model (Correa et al., 2012). They concluded that dangerous values of VOCs concentration can be perceived even 150 m away from the gas station and could affect a hospital, two schools and several residences located nearby the area under investigation. Kountouriotis et al. achieved a more sophisticated numerical simulation of fuel vapour dispersion, which was carried out in the area of a petrol station, and confirmed the effect of filling station on the air contamination of the surrounding area (Kountouriotis et al., 2014). However, a detailed understanding of the three-dimensional distribution of barriers, obstructions, obstacles, etc. is mandatory for obtaining reliable models.

We present here the implementation of an inventive methodology based on the application of a novel device named the Shadow-Ribbon (Monitto and Tuccitto, 2014). This device is able to obtain the position, height and permeability of obstacles by scanning across the streets of industrial plants. The basic idea of our peculiar and innovative approach consists in a multivariate relation that can be found between the influence of a physic obstacle on the dispersion of gaseous substances and the ''shadow'' effect of the same obstacle (i.e. the shielding of a light source). For our purposes, the obstacles consist in all the urban fabrics within a certain city district (e.g. buildings, trees, etc.) and what we investigate is their shielding of sunlight, related to their size (height and width). The gaseous substances to be monitored are all the pollutant vapours diffused by the flow of winds. Using the Shadow Ribbon, equipped with VOCs and light sensors, we are able to collect simultaneously air pollutants and data about the shadowing effect of any kind of obstacle present in an urban area by simply scanning the device through the area we want to monitor. From the shadowing of an object we are then able to reconstruct the map of the area we want to study, basing on the assumptions that a large and high obstacle would result in a complete shadowing of the surrounding area, as well as the vacancy of obstacles would result in the total absence of shadowing. Certainly, all the situations that are intermediate with respect to the above described are taken into account. This classification is transferred to a 2-dimensional chart by means of GPS coordinates, thus giving a map of the investigated area. In addition, by measuring the length of the ''shadows'' we are also able to know the height of these obstacles and subsequently to associate it to the different wind permeability, deduced by the shadow study. By means of such innovative approach, we easily reconstructed maps of bulky obstacles, porous areas and open patch zone. At the same time, we can carry out accurate chemicals dispersion modelling, with no need of performing, separately, detailed 3D measurements of the area with expensive instruments and time-consuming approaches.

Here, we present the very first use of this original approach inside an urban area surrounding a filling station. We made use of a numerical resolution of the Advection–Dispersion equation to calculate in real time the concentration of pollutants. Finally, in order to assess the accuracy of our strategy, analytical detection of pollutants concentration was carried out in the air of the specific area under investigation, and the results confirmed the effectiveness of our approach.

2. Materials and methods

The shadow ribbon was equipped to detect the position, height, temperature, humidity, pressure, luminosity, VOCs concentration and anemometric conditions by using several dedicated sensors. Light sensors (Avago Technologies, Regensburg, DE) were purchased from RS-components. JUPITER SE880 from Telit Communications PLC (High Holborn, London WC1V 6XX, United Kingdom) was used as the GPS module. Photoionisation sensor for VOCs detection was purchased from Alphasense (PID-AH has a linear dynamic range of 5-ppb to 50-ppm). The devices were equipped with The Raspberry